Chapter One

Introduction

1.1. Introduction:

Nuclear medicine is a medical specialty involving the use of radioactive substances in the diagnosis and treatment of disease. In nuclear medicine procedures, radionuclides are combined with other elements to form chemical compounds, or else combined with existing pharmaceutical compounds, to form radiopharmaceuticals. These radiopharmaceuticals, once administered to the patient, can localize to specific organs or cellular receptors, it records radiation emitting from within the body rather than radiation that is generated by external sources. Radiopharmaceuticals allow nuclear medicine the ability to image the extent of a disease process in the body, based on the cellular function and physiology, rather than relying on physical changes in the affected tissue. In some diseases nuclear medicine studies can identify medical problems at an earlier stage than other diagnostic tests. (Mas JC, 2008)

A bone scintigraphy (bone scan) is a diagnostic study used to evaluate the distribution of active bone formation in the body, Bone scintigraphy is one of the most frequently performed of all radionuclide procedures. Radionuclide bone imaging is quick, relatively inexpensive, widely available, and exquisitely sensitive and is invaluable in the diagnostic evaluation of numerous pathologic conditions. The procedure is performed with technetium-99m–labeled diphosphonates. These compounds accumulate rapidly in bone, and by 2–6 hours after injection, about 50% of the injected dose is in the skeletal system. The uptake mechanisms of diphosphonates have not been completely elucidated. Presumably they are adsorbed

to the mineral phase of bone, with relatively little binding to the organic phase. The degree of radiotracer uptake depends primarily on two factors: blood flow and, perhaps more importantly, (B. Tomas, 2003) a nuclear scanning test to find certain abnormalities in bone. It was primarily used to help diagnose a number of conditions relating to bones, including: cancer of the bone or cancers that have spread (metastasized) to the bone, locating some sources of bone inflammation (e.g. bone pain such as lower back pain due to a fracture), the diagnosis of fractures that may not be visible in traditional X-ray images, and the detection of damage to bones due to certain infections and other problems. it is one of a number of methods of bone imaging Such imaging studies include magnetic resonance imaging (MRI) X-ray computed tomography (CT), a nuclear bone scan is a functional test: it measures an aspect of bone metabolism or bone remodeling, which most other imaging techniques cannot. The nuclear bone scan competes with the FDG-PET scan in seeing abnormal metabolism in bones, but it is considerably less expensive. Nuclear bone scans are not to be confused with the completely different test often termed a (bone density scan) DEXA or DXA, which is a low-exposure X-ray test measuring bone density to look for osteoporosis and other diseases where bones lose mass, without any bone-rebuilding activity. In the nuclear medicine technique, the patient is injected (usually into a vein in the arm or hand, occasionally the foot) with a small amount of radioactive material such as 740 MBq of technetium-99m-MDP and then scanned with a gamma camera, a device sensitive to the radiation emitted by the injected material. Two-dimensional projections of scintigraphy may be enough, but in order to view small lesions (less than 1cm), single photon emission computed tomography (SPECT) or positron emission tomography (PET).

Half of the radioactive material leaves the body through the kidneys and bladder in urine. Anyone having a study should empty their bladder immediately before images are taken. In evaluating for tumors, the patient is injected with the radioisotope and returns in 2–3 hours for imaging. Image acquisition takes from 30 to 70 minutes; the three phase bone scan detects different types of pathology in the bone the first phase is also known as the nuclear angiogram or the flow phase. During this phase, serial scans are taken during the first 2 to 5 seconds after injection of the Technetium-99m-MDP. This phase typically shows perfusion to a lesion. Cellulitis shows up more in phase 1 and phase 2 scan, but not in phase 3. Pathology that is more moderate to severe will show more in the first two phases. Pathology that is chronic or partially treated will be more pronounced in the third phase of a triphasic scan. The second phase image, also known as the blood pool image is obtained 5 minutes after injection. This shows the relative vascularity to the area. Areas with moderate to severe inflammation have dilated capillaries, which is where the blood flow is stagnant and the radioisotope can "pool". This phase shows areas of intense or acute inflammation more definitively compared with the third phase. The third phase, delayed phase, is obtained 3 hours after the injection, when the majority of the radioisotope has been metabolized. This phase best shows the amount of bone turnover associated with a lesion. A typical radiation dosage obtained during a bone scan is 6.3 mSv (M. Khalil, 2011).

1.2. Image processing in nuclear medicine:

There is significant development in medical imaging and this return to software development which in turn has provided a major impetus for new algorithms in signal and image processing (S. Mallat, 1999). Image processing is a set of techniques in which the data from an image are analysed and processed using

algorithms and tools to enhance certain image information, noise removal, restoration, Feature detection, compression and image analysis give Segmentation, image registration,and also allow to The processing of an image permits the extraction of useful parameters and increases the possibility of detection of small lesions more accurately. Image processing in nuclear medicine serves three major purposes: the reconstruction of the images acquired with tomographic (SPECT) techniques,, the quality improvement of the image for viewing in terms of contrast uniformity and spatial resolution, and the preparation of the image in order to extract useful diagnostic qualitative and quantitative information medical images analysis and enhancement by image processing (Lyra, 2011).

1.3. Problem of Study:

Medical images are often deteriorated by many defects due to several of interference and other factor associated with imaging process and data acquisition system. Digital images are prone to a variety of types of noise. There are several ways that noise can be introduced into an image, depending on how the image is created. The nature of the physiological system under investigation and procedures used in imaging also diminish the contrast and the visibility of details.Sometimes information is not available a priori to identify the useful intensity bands.Radiation is a major risk in diagnostic in medical image. The problem is caused from overdose during the diagnosis due to improve the image.

1.4. Objectives of study:

- Enhancement of bone scintigraphy image by using image processing techniques.
- Obtaining of high image quality by image processing from first time is reduce of overdose by repeat the examination to get the high image quality.

1.4.1 Specific objective:

- To improve the contrast and resolution of bone scan image according to the enhancement image techniques in MATLAB and to increase the contrast of the output image using Adjust image intensity values and contrast stretch image codes.

- To reduce ***"salt and pepper"*** noise from the images (bone scan) by used 2-D median filtering**.**

- To decreasing the amplifying of any noise that might be present in the image using Contrast-limited adaptive histogram equalization (CLAHE) technique.

- To extract the foreground from the background using histogram as guide for threshold value.

1.5. Overview of the Study:

This thesis is concerned with the Enhancement of bone scintigraphy image by using image processing techniques. This study falls into five chapters, Chapter one, which is an introduction, It presents the statement of the study problems, objectives of the study, chapter two, contains the background material for the thesis. Specifically it discusses the using of image processing in bone scan and the different methods use to enhance of bone scan image and how can do these techniques, Chapter three describes the materials and a method used to enhancement of bone scintigraphy and explains in details the methods used, Chapter fours deals with results and discussions Chapter five conclusions, recommendations and references.

Chapter Two

Literature Review

2.1. Ionizing Radiation:

Ionizing (high-energy) radiation has the ability to remove electrons from atoms; i.e., to ionize the atoms. Ionizing radiation can be electromagnetic or particulate radiation. Clinical diagnostic radiation uses photons (electromagnetic) as radiation in the diagnosis of disease and some benign conditions. Gamma rays are electromagnetic radiation of the shortest wavelength and highest energy of an extremely high frequency and are therefore high energy photons, Gamma ray are ionizing radiation and the most penetrating from the radiation, thus biologically hazardous, symbol is γ. Gamma rays have the same property as X-rays, but are generated different X-ray through energetic electron interactions. (L'Annunziata and Michael, 2007)

Production of Gamma ray: Gamma Decay (Isometric Transition) is a nucleus (which is unstable) changes from a higher energy state to a lower energy state through the emission of electromagnetic radiation (photons) (called gamma rays). The daughter and parent atoms are isomers, Gamma-ray through isometric transition in nucleus (Dendy, 1999).

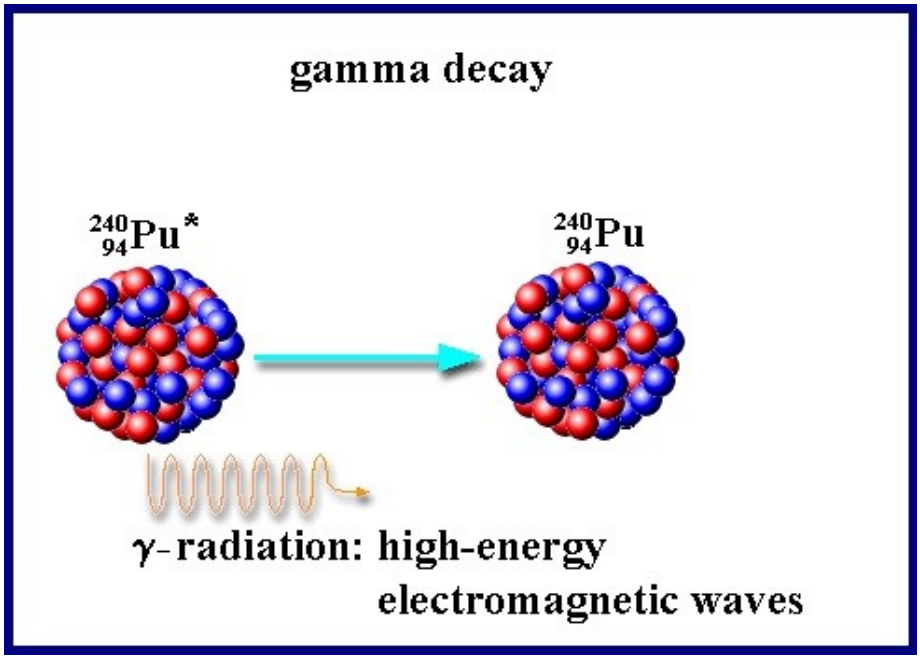

Figure 2-1. Gamma Decay (Karl, 2003)

After Positron Decay the positron later annihilates a free electron; generate two gamma photons in opposite directions. The two photons each have energy 511 KeV, which is the energy equivalent to the rest mass of an electron or positron. These gamma rays are used for medical imaging (Positron Emission Tomography), detected using a coincidence detection circuit (Dendy, 1999).

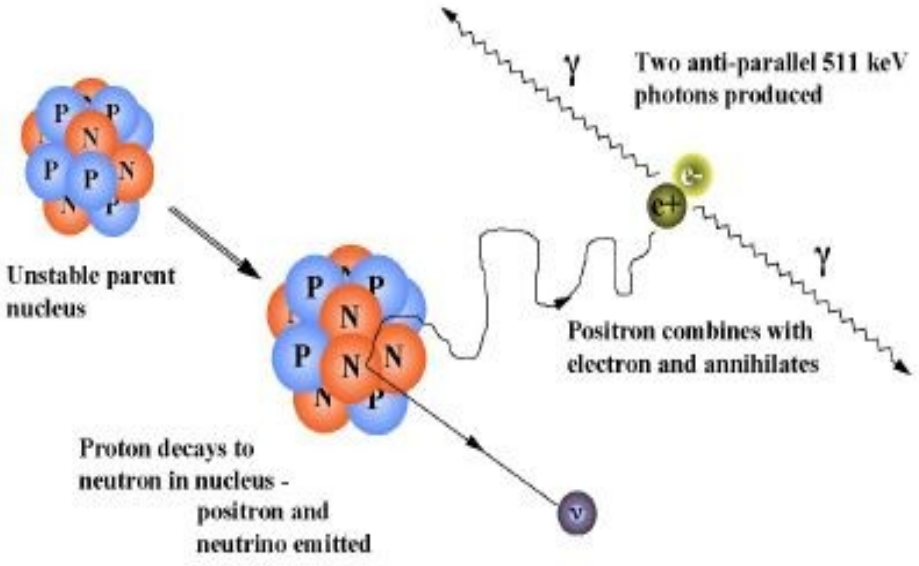

Figure 2-2.Mutual Annihilation after Positron Decay (Rickey et al 1992)

2.2. The human skeleton anatomy:

The human skeleton is the internal framework of the body. It is composed of 270 bones at birth – this total decreases to 206 bones by adulthood after some bones have fused together. The bone mass in the skeleton reaches maximum density around age 30, the human skeleton can be divided into the axial skeleton and the appendicular skeleton. The axial skeleton is formed by the vertebral column, the rib cage and the skull. The appendicular skeleton, which is attached to the axial skeleton, is formed by the pectoral girdle, the pelvic girdle and the bones of the upper and lower limbs. The human skeleton serves six major functions; support, movement, protection, production of blood cells, storage of ions and endocrine regulation (Cavendish. 2010).

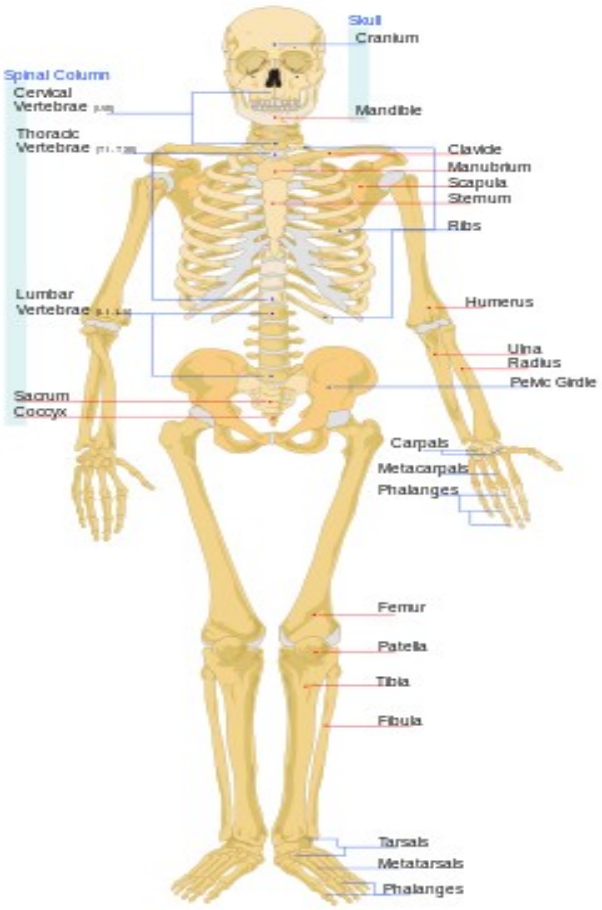

Figure 2-3. Human skeleton (Heller et al, 2003)

2.3. Nuclear medicine:

Nuclear medicine is a medical specialty involving the application of radioactive substances in the diagnosis and treatment of disease. Nuclear medicine scans are usually conducted by Radiographers. In nuclear medicine procedures, radionuclide's are combined with other elements to form chemical compounds, or else combined with existing pharmaceutical compounds, to form pharmaceuticals. These radio pharmaceuticals, once administered to the patient, can localize to specific organs or cellular receptors. This property of radio pharmaceuticals allows nuclear medicine the ability to image the extent of a disease process in the body, based on the cellular function and physiology, rather than relying on physical changes in the tissue anatomy. In some diseases, nuclear medicine studies can identify medical problems at an earlier stage than other diagnostic tests. Nuclear medicine, in a sense, is radiology (done inside out), because it records radiation emitting from within the body rather than radiation that is generated by external sources like x-rays. Treatment of diseased tissue, based on metabolism or uptake or binding, however, the treatment effects of radiopharmaceuticals rely on the tissue-destructive power of short-range ionizing radiation (Henkin R. et al, 1996).

2.3.1. Diagnostic medical imaging

In nuclear medicine imaging, radiopharmaceuticals are taken internally, for example, intravenously or orally. Then, external detectors (gamma cameras) capture and form images from the radiation emitted by the radiopharmaceuticals.

Nuclear medicine tests differ from most other imaging modalities in that diagnostic tests primarily show the physiological function of the system being investigated as opposed to traditional anatomical imaging such as CT or MRI.

- 2D: Scintigraphy is the use of internal radionuclide's to create two-dimensional images.

A nuclear medicine whole body bone scan. The nuclear medicine whole body bone scan is generally used in evaluations of various bone related pathology, such as for bone pain, stress fracture, nonmalignant bone lesions, bone infections, or the spread of cancer to the bone (Ell and Gambhir , 2004).

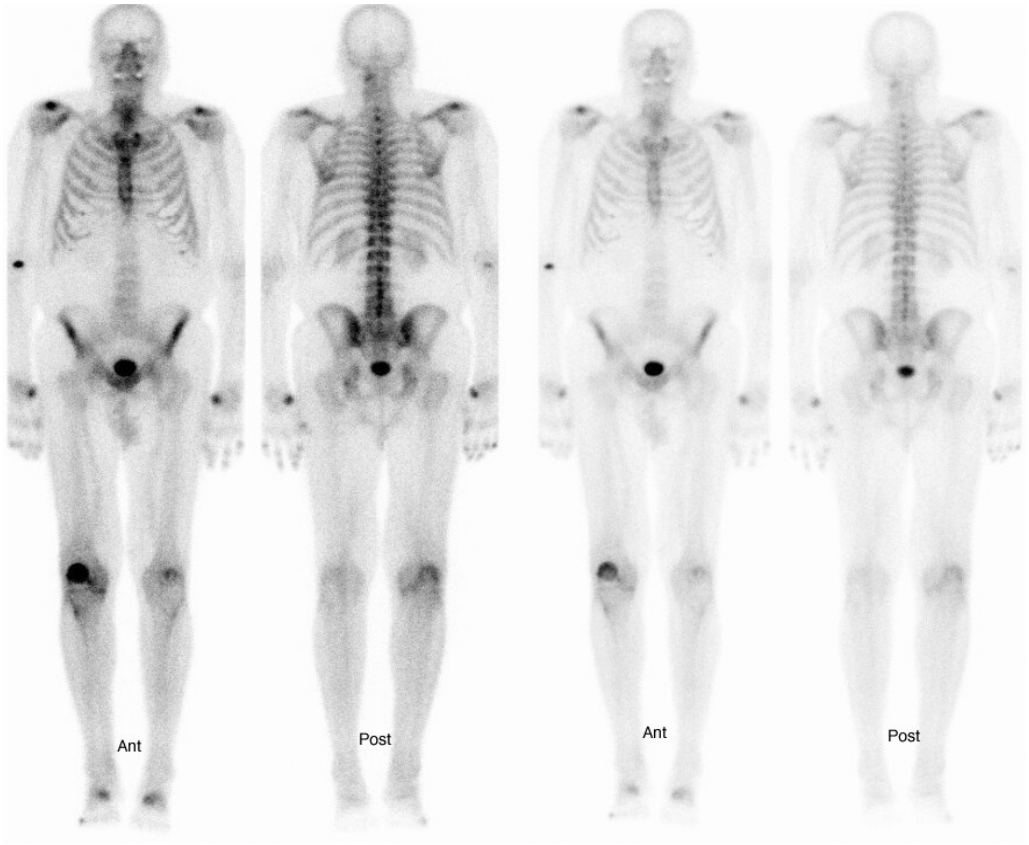

Figure 2-4.bone scintigraphy (Cook GJ, 2002)

- 3D: SPECT and PET are 3D. Single photon emission computed tomography (SPECT) is tomographic technique that uses gamma camera data from many projections and can be reconstructed in different planes (Ell and Gambhir, 2004) (Taylor A et al, 2000).

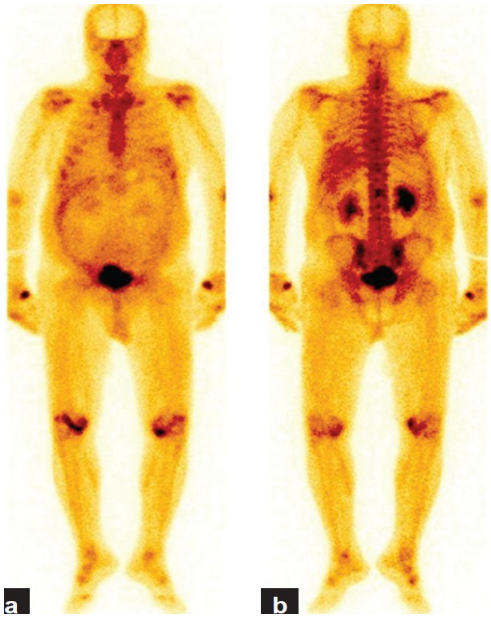

Figure 2-5.bone scans (Hess KR, 2006)

Positron emission tomography (PET) uses coincidence detection to image functional processes (Ell and Gambhir , 2004) (Taylor A et al, 2000)**.**

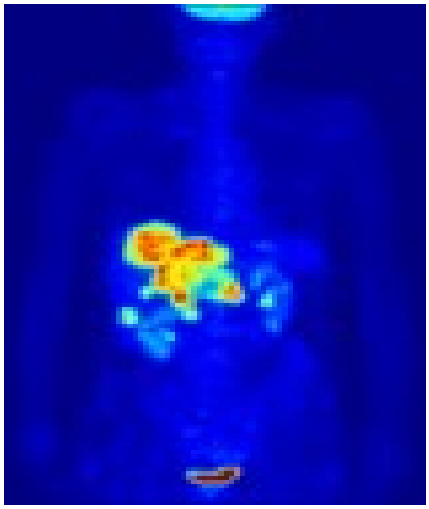

Figure 2-6. Whole-body PET scan using ^{18}F-FDG (Maher et al, 2006) (Newberg A, 2002)

Diagnostic tests in nuclear medicine exploit the way that the body handles substances differently when there is disease or pathology present. The radionuclide introduced

into the body is often chemically bound to a complex that acts characteristically within the body; this is commonly known as a tracer. In the presence of disease, a tracer will often be distributed around the body and/or processed differently. For example, the ligand methylene-diphosphonate (MDP) can be preferentially taken up by bone. By chemically attaching technetium-99mto MDP, radioactivity can be transported and attached to bone via the hydroxyapatite for imaging. Any increased physiological function, such as due to a fracture in the bone, will usually mean increased concentration of the tracer. This often results in the appearance of a "hot spot", which is a focal increase in radio accumulation or a general increase in radio accumulation throughout the physiological system. Some disease processes result in the exclusion of a tracer, resulting in the appearance of a "cold spot". Many tracer complexes have been developed to image or treat many different organs, glands, and physiological processes (Ell and Gambhir, 2004) (Taylor A et al, 2000).

2.4. Bone scintigraphy:

Skeletal scintigraphy or bone scan is a special type of nuclear medicine procedure that uses small amounts of radioactive material to diagnose and determine the severity of a variety of bone diseases and conditions, including fractures, infection, and cancer. Nuclear medicine imaging procedures are noninvasive and–with the exception of intravenous injections–usually painless medical tests that help physicians diagnose and evaluate medical conditions. These imaging scans use radioactive materials called radiopharmaceuticals or radiotracers. Radioactive energy emitted from the radiotracer is detected by a special camera or imaging device that produces pictures of the bones called scintigrams. Abnormalities are indicated by areas of abnormal bone that take up more or less of the radiopharmaceutical which appear brighter or darker than normal bone on the scintigram. Because nuclear medicine procedures are able to

image the functions of the body at the molecular level, they offer the potential to identify disease in its earliest stages as well as a patient's immediate response to therapeutic interventions. This builds up an image of the bone structure, as determined by the blood flow in the bones and the activity of the bone to generate cells, In fact, a skeletal scintigram or bone scan can often find bone abnormalities much earlier than a regular x-ray exam. Bone scintigraphy images the distribution of a radioactive tracer in the skeletal system, it can be performed as:

- Limited bone scintigraphy or spot views (planar images of a selected portion of the skeleton).
- Whole-body bone scintigraphy (planar images of the entire skeleton in anterior and posterior views).
- SPECT (tomographic image of a portion of the skeleton).
- Multiphase bone scintigraphy (immediate and delayed images to study blood flow).

In oncology the standard technique of bone scintigraphy is considered to be the whole-body scan (Brown and collier, 1993) (Collier BD, 1996)**.**

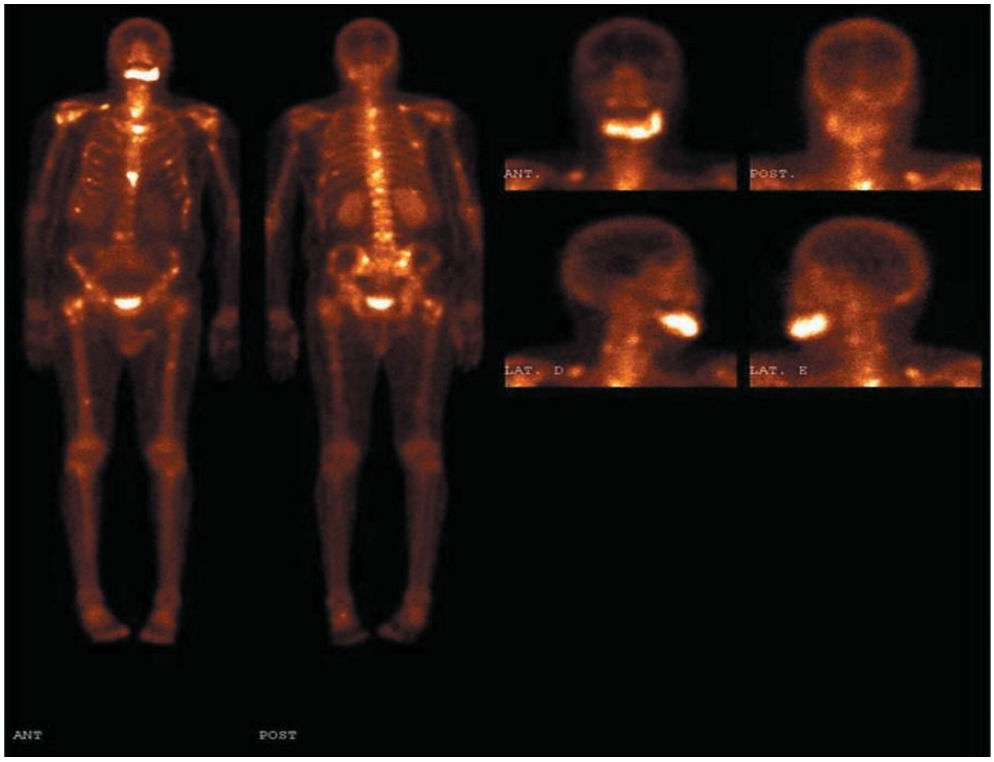

Figure 2-7. Whole-body bone scan with Oral metastases (Van and Buter, 2003)

Physicians order skeletal scintigraphy to:

- Find bone cancer or determine whether cancer from another area of the body, such as the breast, lung or prostate gland, has spread to the bones.
- Diagnose the cause or location of unexplained bone pain, such as ongoing low back pain.
- Help determine the location of an abnormal bone in complex bone structures, such as the foot or spine. Follow-up evaluation may then be done with a computed tomography (CT) or magnetic resonance imaging (MRI) scan.
- Diagnose broken bones, such as a stress fracture or a hip fracture, not clearly seen on x-rays.
- Find bone damage caused by infection or other conditions. (Brown and collier, 1993) (Collier BD, 1996).

A bone scan carries no more risk than conventional X-rays. The tracers in the radioactive dye used in a bone scan produce very little radiation exposure. Even the risk of allergic reaction to the tracers is low. May be feeling a slight discomfort at the injection site and sitting still during the test can be uncomfortable for some people. The greater risk is to pregnant or nursing women.

Test results of bone scan are considered normal if the radiotracer moves evenly throughout all the bones. And an abnormal scan will show “hot spots” and/or “cold spots” as compared to surrounding bone. Hot spots are areas where there is an increased accumulation of the radioactive material; Cold spots are areas that have taken up less of the radioactive material (Coleman and Holen, 2008) (Pretorius and Solomon, 2010).

2.4.1. Radiopharmaceutical:

The use of specific radiotracers called radiopharmaceuticals for imaging organ function and disease states is a unique capability of nuclear medicine. Unlike other imaging modalities , nuclear medicine procedures are capable of mapping physiological function and metabolic activity and thereby giving more specific information about the organ function The mapping of the radiopharmaceutical distribution in vivo provides images of functional morphology of organs in a non-invasive manner and plays an important role in the diagnosis of many common diseases associated with the malfunctioning of organs in the body as well as in the detection of certain type of cancers (Saha, 2010).

2.4.2. Gamma camera:

A gamma camera, also called a scintillation camera or Anger camera. Is a device used to image gamma radiation emitting radioisotopes, a technique known as scintigraphy.

The applications of scintigraphy include early drug development and nuclear medical imaging to view and analyze images of the human body or the distribution of medically injected, inhaled, or ingested radionuclides emitting gamma. The basic design of the most common type of gamma camera used today was developed by an American physicist, Hal Anger.

In 1958: Hal Anger (hence name sometimes used: "Anger camera") with 10cm diameter circular NaI(Tl) crystal, pinhole collimator, photomultiplier tubes 7 PMTs, images of thyroid with 131I and the first commercial gamma camera(Pho/Gamma) in 1962 **(**J . J. Pedroso de Lima**,** 2010).

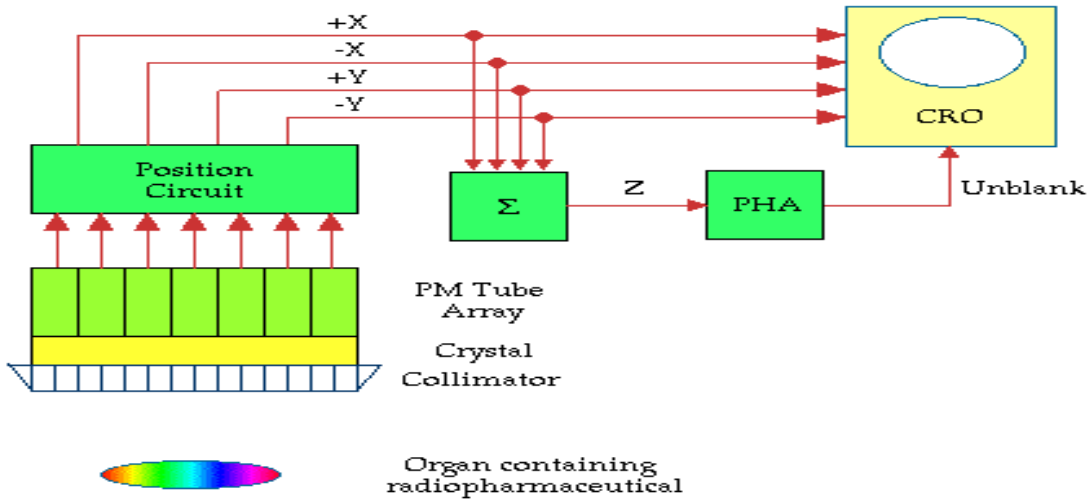

Figure 2-8. Diagram of a gamma camera (Maher et al, 2006) (Gunter DL, 2006)

Basic components of Gamma Cameras

- Collimator: restricts acceptance angle
- Scintillation crystals NaI(Tl): scintillator
- Light guide: spreads light uniformly
- Photoelectron multiplier tube PMTs: light to current converter
- Position/summing circuit: position (x, y), summing Z ("unblank")
- Pulse Height Analysis PHA: energy discrimination

- Acquisition computer/matrix: Position signals converted to digital
- Correction circuits: energy, linearity (cherry et al, 2012)

2.5. Image Processing:

Image processing is a method to convert an image into digital form and perform some operations on it, in order to get an enhanced image or to extract some useful information from it. It is a type of signal dispensation in which input is image, like video frame or photograph and output may be image or characteristics associated with that image. Usually Image Processing system includes treating images as two dimensional signals while applying already set signal processing methods to them.

It is among rapidly growing technologies today, with its applications in various aspects of a business. Image Processing forms core research area within engineering and computer science disciplines too.

Image processing basically includes the following three steps:

- Importing the image with optical scanner or by digital photography.
- Analyzing and manipulating the image which includes data compression and image enhancement and spotting patterns that are not to human eyes like satellite photographs.
- Output is the last stage in which result can be altered image or report that is based on image analysis. (Tinku, Ajoy K, 2005).

2.5.1. Purpose of Image processing:

The purpose of image processing is divided into 5 groups. They are:

- Visualization - Observe the objects that are not visible.
- Image sharpening and restoration - To create a better image.
- Image retrieval - Seek for the image of interest.

- Measurement of pattern – Measures various objects in an image.
- Image Recognition – Distinguish the objects in an image.

Types of methods in Image Processing: The two types of methods used for Image Processing are Analog and Digital Image Processing. Analog or visual techniques of image processing can be used for the hard copies like printouts and photographs. Image analysts use various fundamentals of interpretation while using these visual techniques. The image processing is not just confined to area that has to be studied but on knowledge of analyst. Association is another important tool in image processing through visual techniques. So analysts apply a combination of personal knowledge and collateral data to image processing.

Digital Processing techniques help in manipulation of the digital images by using computers. As raw data from imaging sensors from satellite platform contains deficiencies. To get over such flaws and to get originality of information, it has to undergo various phases of processing. The three general phases that all types of data have to undergo while using digital technique are Pre- processing, enhancement and display, information extraction (Tinku, Ajoy K, 2005).

2.5.2. Image Processing Toolbox:

Advanced techniques of image processing and analysis find widespread use in medicine. In medical applications, image data are used to gather details regarding the process of patient imaging whether it is a disease process or a physiological process. Information provided by medical images has become a vital part of today's patient care. The images generated in medical applications are complex and vary notably from application to application. Nuclear medicine images show characteristic information about the physiological properties of the structures-organs. In order to have high quality medical images for reliable diagnosis, the processing of image is

necessary. The scope of image processing and analysis applied to medical applications is to improve the quality of the acquired image and extract quantitative information from medical image data in an efficient and accurate way**.** (lyra, 2011) The Image Processing Toolbox is a collection of functions that extend the capability of the MATLAB numeric computing environment. The toolbox supports a wide range of image processing operations, including:

- Spatial image transformations.
- Morphological operations.
- Neighborhood and block operations.
- Linear filtering and filter design.
- Transforms.
- Image analysis and enhancement.
- Image registration.
- Deblurring.
- Region of interest operations. (MathWorks, 2001).

2.5.3. Image Processing Demos:

The Image Processing Toolbox is supported by a full complement of demo applications. These are very useful as templates for your own end-user applications, or for seeing how to use and combine your toolbox functions for powerful image analysis and enhancement. Matlab (Matrix Laboratory) is a high performance interactive software package for scientific and engineering computation developed by Math Works. Matlab allows matrix computation, implementation of algorithms, simulation, plotting of functions and data, signal and image processing by the Image Processing Toolbox. It enables quantitative analysis and visualization of nuclear

medical images of several modalities, such as Single Photon Emission Computed Tomography (SPECT), Positron Emission Tomography (PET) or a hybrid system (SPECT/CT) where a Computed Tomography system (CT) is incorporated to the SPECT system. Many of the toolbox functions are MATLAB M-files, a series of MATLAB statements that implement specialized image processing algorithms, could view the MATLAB code for these functions using the statement. The capabilities of the Image Processing Toolbox could extend by writing M-files, or by using the toolbox in combination with other toolboxes, such as the Signal Processing Toolbox and the Wavelet Toolbox (Lyra et al, 2011).

2.6. Nuclear Medicine imaging:

Nuclear Medicine is the section of science that utilizes the properties of radiopharmaceuticals in order to derive clinical information of the human physiology and biochemistry. In Nuclear Medicine, there are two main methods of patient imaging, the imaging with Planar Imaging, Dynamic Imaging or SPECT and the PET. During the last decade, hybrid systems have been developed integrating the CT technique with either SPECT or PET resulting in SPECT/CT and PET/CT respectively. This chapter will concentrate on the implementation of Matlab code in gamma camera planar imaging methods. (Lyra et al, 2011)

2.6.1. Image quality in nuclear medicine:

Image quality plays an important role in nuclear medicine imaging as the goal is a reliable image of the projected organ to be provided, for accurate diagnosis or therapy. The physical characteristics that are used to describe image quality are:

- Contrast.
- Spatial resolution.
- Noise.

Image contrast is the difference in intensity corresponding to different concentration of activity in the patient. For high diagnostic accuracy, nuclear medicine images must be of high contrast. The image contrast is principally affected by the radiopharmaceutical that is used for imaging and the scattered radiation. In general, it is desirable to use a radiopharmaceutical which has a high uptake within the target organ (Wernick and Aarsvold, 2004).

Spatial resolution is defined as the ability of the imaging modality to reproduce the details of a nonuniform radioactive distribution. The spatial resolution is separated into intrinsic resolution (scintillator, photomultiplier tubes and electronic circuit) and system resolution (collimator, scintillator, photomultiplier tubes and electronic circuit). The intrinsic resolution depends on the thickness of scintillation crystal while the system resolution depends mainly on the distance from the emitting source to collimator. The resolution of a gamma camera is limited by several factors. Some of these are the patient motion, the statistical fluctuation in the distribution of visible photons detected and the collimators geometry.

Noise refers to any unwanted information that prevents the accurate imaging of an object.

Noise is the major factor in the degradation of image quality. Image noise may be divided into random and structured noise. Image processing in nuclear medicine serves three major purposes:

- The reconstruction of the images acquired with tomographic (SPECT) techniques.
- The quality improvement of the image for viewing in terms of contrast, uniformity and spatial resolution.

- The preparation of the image in order to extract useful diagnostic qualitative and quantitative information. (Lyra, et al, 2011)

2.6.2. Image analysis and processing in nuclear medicine:

In the last several decades, medical imaging systems have advanced in a dynamic progress. There have been substantial improvements in characteristics such as sensitivity, resolution, and acquisition speed. New techniques have been introduced and, more specifically, analogue images have been substituted by digital ones. As a result, issues related to the digital images' quality have emerged (Nailon, 2010).

2.7. Digital images:

The digitization of images generally consists of two concurrent processes Image Sampling: This process is used to digitise the spatial information in an image. It is typically achieved by dividing an image into a square or rectangular array of sampling points. Each of the sampling points is referred to as a picture element - or pixel to use computer jargon**.** Naturally, the larger the number of pixels, the closer the spatial resolution of the digitized image approximates that of the original analogue image. Image Quantisation: This process refers to the digitisation of the brightness information in an image. It is typically achieved by representing the brightness of a pixel by an integer whose value is proportional to the brightness. This integer is referred to as a 'pixel value' and the range of possible pixel values which a system can handle is referred to as the gray scale. Naturally, the greater the gray scale, the closer the brightness information in the digitised image approximates that of the original, analogue image (Gonzalez, R et al, 2009).

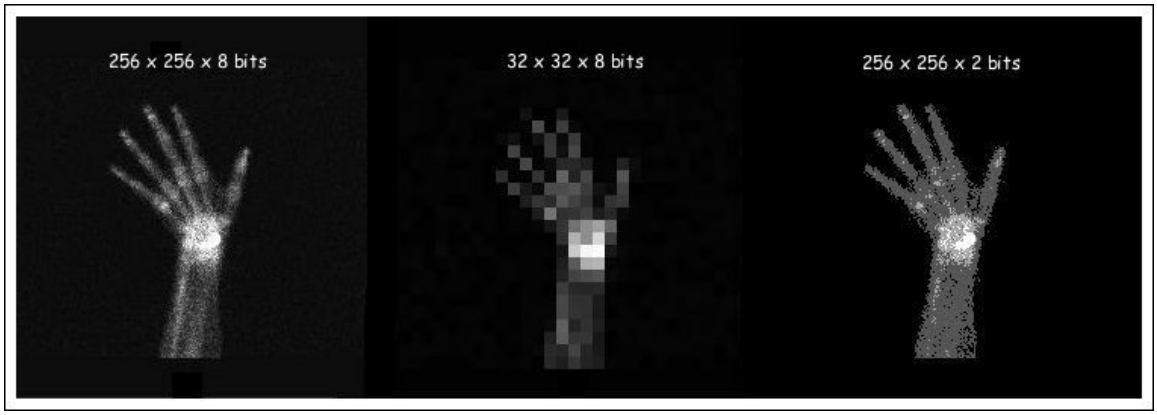

Figure 2-9. A bone scan of a patient's hand displayed with digital image resolutions of 256x256x8 bits, 32x32x8 bits and 256x256x2 bits (Maher et al, 2006)

In all modern nuclear medicine imaging systems, the images are displayed as an array of discrete picture elements (pixels) in two dimensions (2D) and are referred as digital images. Each pixel in a digital image has an intensity value and a location address, In a nuclear medicine image the pixel value shows the number of counts recorded in it. The benefit of a digital image compared to the analogue one is that data from a digital image are available for further computer processing (Lyra, et al, 2011)

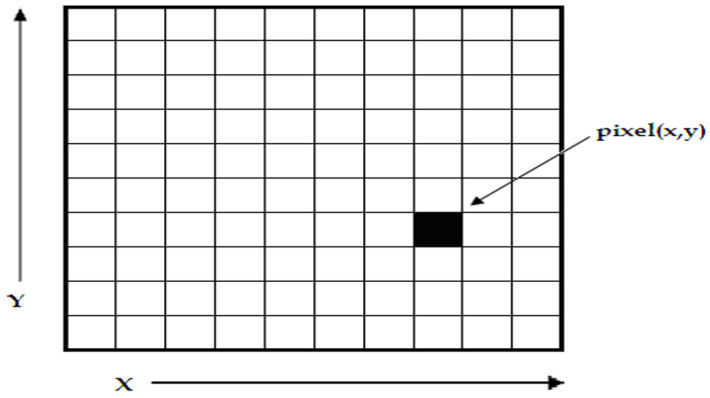

Figure 2-10. A digital image is a 2D array of pixels each pixel is characterized by its (x, y) coordinates and its value (Lyra, et al, 2011)

Digital images are characterized by matrix size, pixel depth and resolution. The matrix size is determined from the number of the columns (m) and the number of rows (n) of the image matrix (m×n). The size of a matrix is selected by the operator.

Of Nuclear medicine images matrices are, nowadays, ranged from 64×64 to 1024×1024 pixels (Gonzalez et al., 2009).

Pixel or bit depth refers to the number of bits per pixel that represent the colour levels of each pixel in an image. Each pixel can take 2k different values, where k is the bit depth of the image. This means that for an 8-bit image, each pixel can have from 1 to 28 (=256) different colour levels (grey-scale levels). Nuclear medicine images are frequently represented as 8- or 16- bit images.

The term resolution of the image refers to the number of pixels per unit length of the image. In digital images the spatial resolution depends on pixel size. The pixel size is calculated by the Field of View (FoV) divided by the number of pixels across the matrix. For a standard FoV, an increase of the matrix size decreases the pixel size and the ability to see details is improved. (Lyra, et al, 2011)

2.7.1 Types of images in the Image Processing Toolbox:

The image types supported from the Image Processing Toolbox from different types.

Binary Images: in these, pixels can only take 0 or 1 value, black or white.

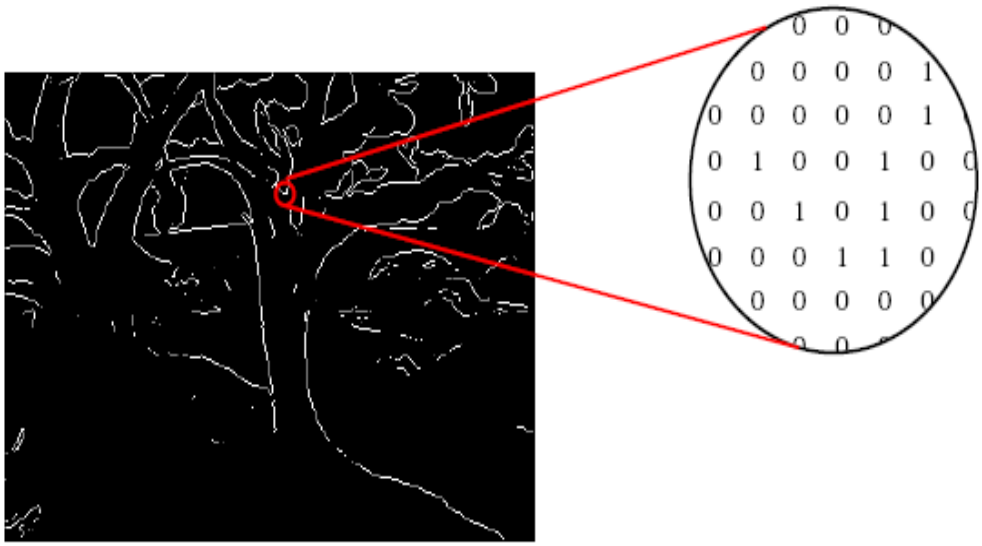

Figure 2-11 Binary image (MathWorks, 2001)

Intensity images: (Grey scale) the image data in a grey scale image represent intensity or brightness. The integers' value is within the range of [0…1], where k is the bit depth of the image. For a typical grey scale image each pixel can represented by 8 bits and intensity values are in the range of [0…255], where 0 corresponds to black and 255 to white.

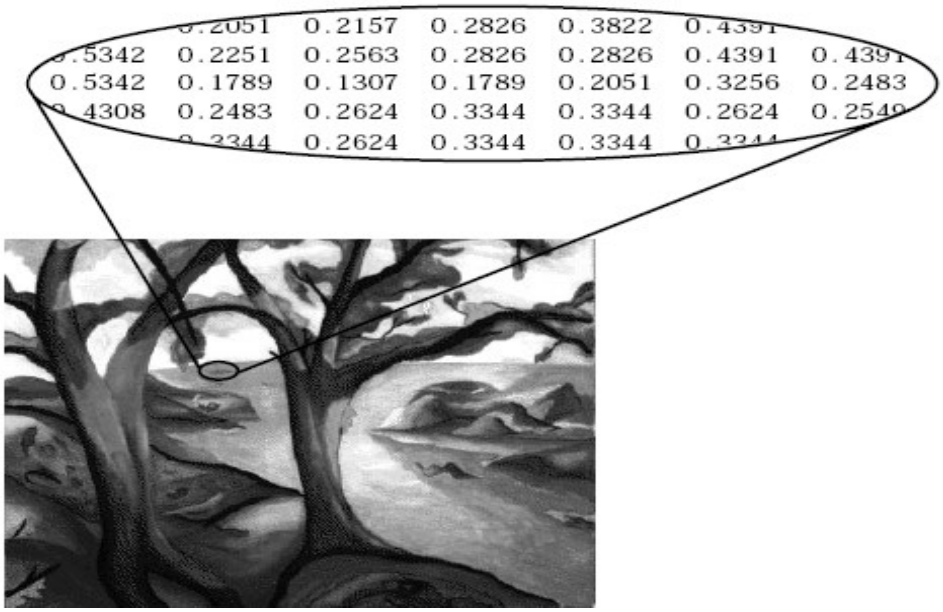

Figure 2-12. Intensity image of class double (MathWorks, 2001)

True color or RGB: in these, an image can be displayed using three matrices, each one corresponding to each of red-green-blue colour. If in an RGB image each component uses 8 bits, then the total number of bits required for each pixel is 3×8=24 and the range of each individual colour component is [0…255]

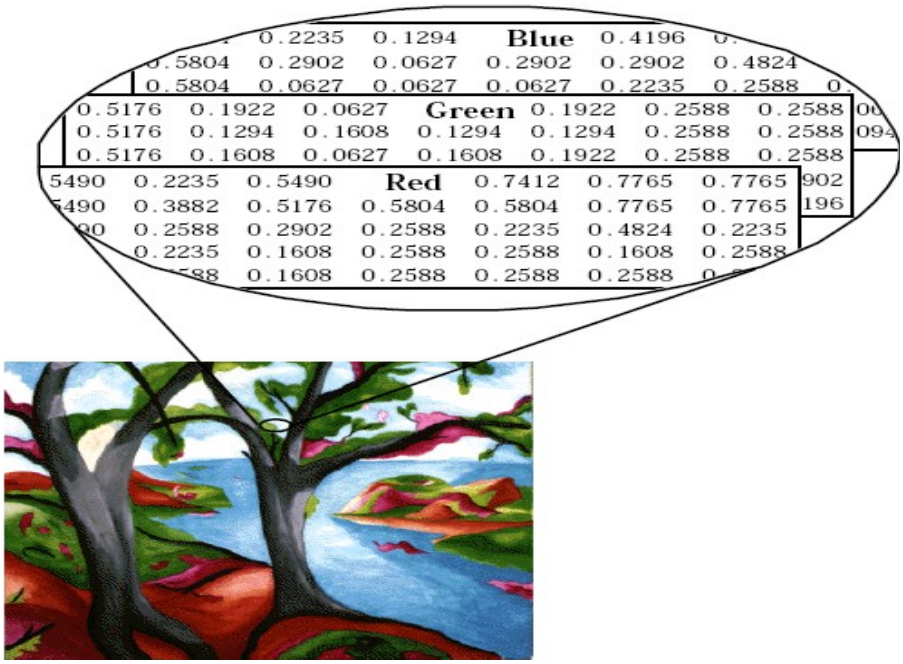

Figure 2-13. RGB image of class double (MathWorks, 2001)

Indexed images: consist of a 2D matrix together with an m×3 colour map (m= the number of the columns in image matrix). Each row of map specifies the red, green, and blue components of a single colour. An indexed image uses direct mapping of pixel values to colour map values. The colour of each image pixel is determined by using the corresponding value of matrix as an index into map. The figure below illustrates the structure of an indexed image. The pixels in the image are represented by integers, which are pointers (indices) to color values stored in the color-map (MathWorks, 2001).

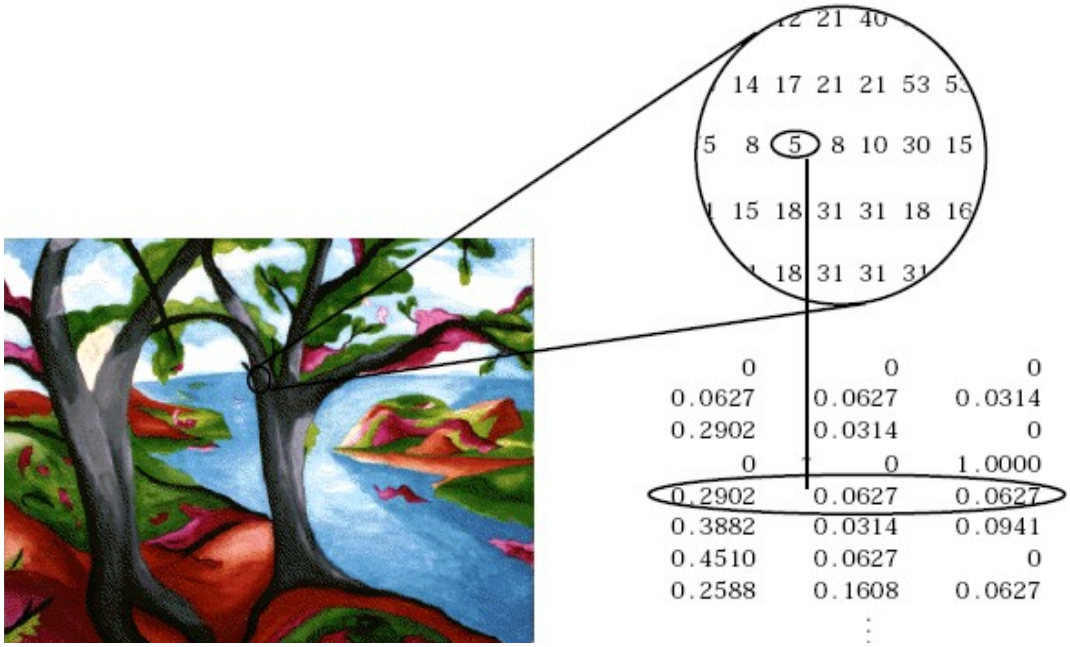

Figure 2-14. Indexed image of class double (MathWorks, 2001)

2.7.2. Converting the Image Type:

For certain operations, it is helpful to convert an image to a different image type. The Image Processing Toolbox provides several functions that enable you to convert any image to another image type. These functions have mnemonic names. The grey scale image is the most convenient and preferable type utilized in nuclear medicine image processing. When coloring depiction is needed, the RGB one should be used and processed. The indexed type images should be converted to any of the two other types in order to be processed. The functions used for image type conversion are rgb2gray,ind2rgb, ind2gray and reversely. Any image can be also transformed to binary one using the command: im2bw. Moreover, in any image, the function impixelinfo can be used in order to detect any pixel value. The user can move the mouse cursor inside the image and the down left corner appears the pixel identity (x, y) as well as the (RGB) values. The pixel range of the image can be displayed by the command imdisplayrange (MathWorks, 2001)

2.7.3. Image filtering:

The factors that degrade the quality of nuclear medicine images result in blurred and noisy images with poor resolution. One of the most important factors that greatly affect the quality of clinical nuclear medicine images is image filtering. Image filtering is a mathematical processing for noise removal and resolution recovery. The goal of the filtering is to compensate for loss of detail in an image while reducing noise. Filters suppressed noise as well as deblurred and sharpened the image. In this way, filters can greatly improve the image resolution and limit the degradation of the image.

An image can be filtered either in the frequency or in the spatial domain. In the first case the initial data is Fourier transformed, multiplied with the appropriate filter and then taking the inverse Fourier transform, re-transformed into the spatial domain.

The filtering in the spatial domain demands a filter mask (it is also referred as kernel or convolution filter). The filter mask is a matrix of odd usually size which is applied directly on the original data of the image. The mask is centered on each pixel of the initial image. For each position of the mask the pixel values of the image is multiplied by the corresponding values of the mask. The products of these multiplications are then added and the value of the central pixel of the original image is replaced by the sum. This must be repeated for every pixel in the image.

If the filter, by which the new pixel value was calculated, is a linear function of the entire pixel values in the filter mask (e.g. the sum of products), then the filter is called linear. If the output pixel is not a linear weighted combination of the input pixel of the image then the filtered is called non-linear.

According to the range of frequencies they allow to pass through filters can be classified as low pass or high pass. Low pass filters allow the low frequencies to be

retained unaltered and block the high frequencies. Low pass filtering removes noise and smooth the image but at the same time blur the image as it does not preserve the edges. High pass filters sharpness the edges of the image (areas in an image where the signal changes rapidly) and enhance object edge information. A severe disadvantage of high pass filtering is the amplification of statistical noise present in the measured counts.

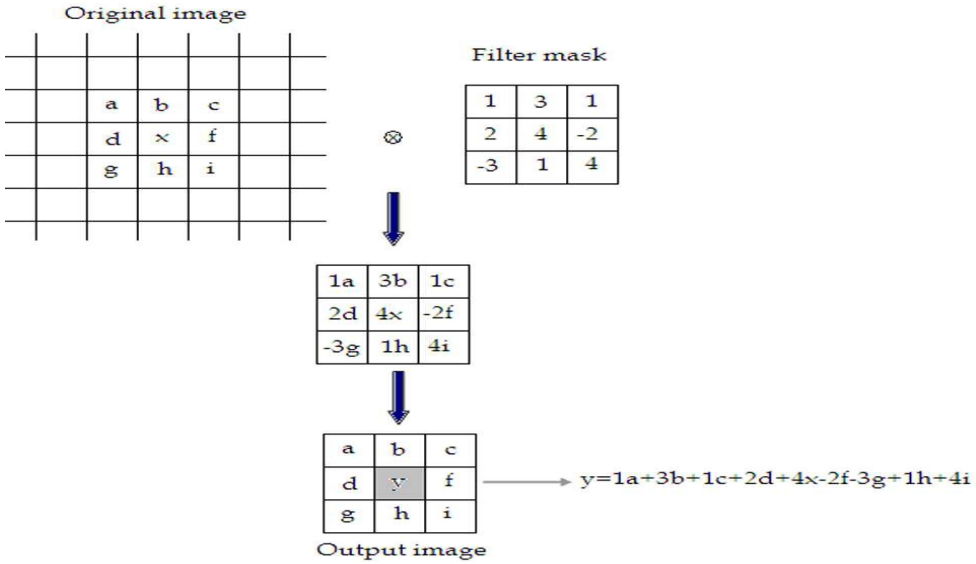

Figure 2-15. Filtering process in spatial domain (lyra et al, 2011)

The most common filters used by MatLab: the mean, median and Gaussian filter.

Mean filter: is the simplest low pass linear filter. It is implemented by replacing each pixel value with the average value of its neighbourhood. Mean filter can be considered as a convolution filter. The smoothing effect depends on the kernel size. As the kernel size increases, the smoothing effect increases too (lyra et al, 2011).

a	b	c
d	e	f
g	h	i

$$\longrightarrow \frac{1}{9}(a+b+c+d+e+f+g+h+i)$$

Figure 2-16. Function of Mean filter (lyra et al, 2011)

Median filter: is a non linear filter. Median filtering is done by replacing the central pixel with the median of all the pixels value in the current neighborhood. A median filter is a useful tool for impulse noise reduction The impulse noise (it is also known as salt and paper noise) appears as black or (/and) white pixels randomly distributed all over the image. (Toprak, A. and Guler, I., 2006)

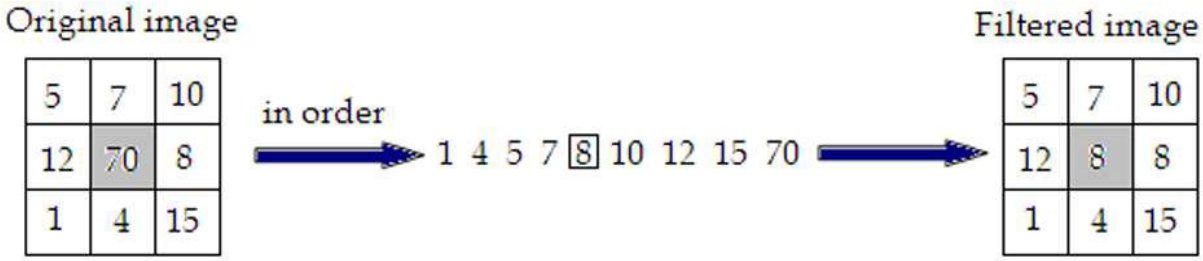

Figure 2-17. Function of Median filter (lyra, 2011)

Gaussian filter: is a linear low pass filter. A Gaussian filter mask has the form of a bellshaped curve with a high point in the centre and symmetrically tapering sections to either side. Application of the Gaussian filter produces, for each pixel in the image, a weighted average such that central pixel contributes more significantly to the result than pixels at the mask edge (Lyra, et al, 2011). The weights are computed according to the Gaussian function (Eq.1):

$$f(x) = 1 \; e^{-(x-\mu)^2/(2\sigma^2)}$$

$$\sigma\sqrt{2\pi}$$

Where μ, is the mean and σ, the standard deviation (O'Gorman et al., 2008)

The degree of smoothing depends on the standard deviation. The larger the standard deviation, the smoother the image is depicted. The Gaussian filter is very effective in the reduction of impulse and Gaussian noise. Gaussian noise is caused by random

variations in the intensity and has a distribution that follows the Gaussian curve. (lyra, 2011)

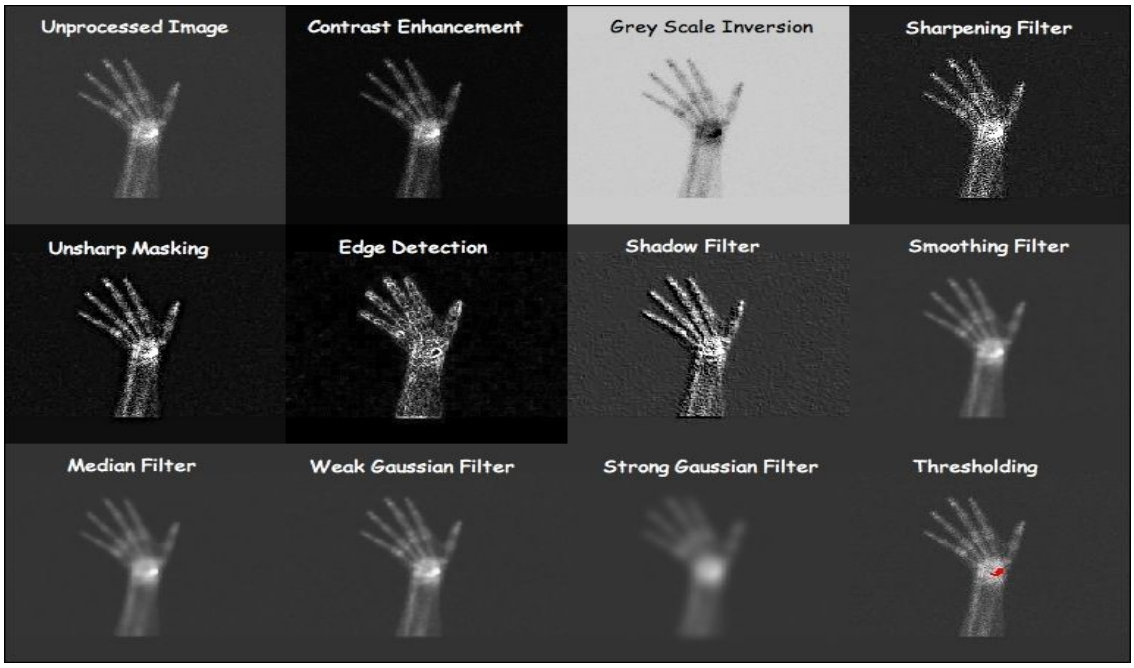

Figure 2-18. Image processing options based on the same unprocessed bone scan shown in top left (Maher et al, 2006)

The Fourier transform (ft) in image processing: In an attempt to convey more effectively the concept on which the transform is based; it does in no way substitute for a rigorous mathematical treatment, and is solely aimed at supporting your understanding of image filtering. This presentation will demonstrate that images can be thought about from both spatial and spatial frequency perspectives. The spatial perspective is the conventional way of presenting image data and relates to real world parameters such as distance and time. An image may also be considered as consisting of a large number of spatial frequencies interacting with each other. This aspect will be examined using a chest radiograph, an example of medical image which consists of a very broad range of spatial frequencies. The Fourier transforms (ft) the image data from the **spatial** representation to the **spatial frequency** representation and the inverse **FT** performs the reverse operation (Gorman et al, 2008).

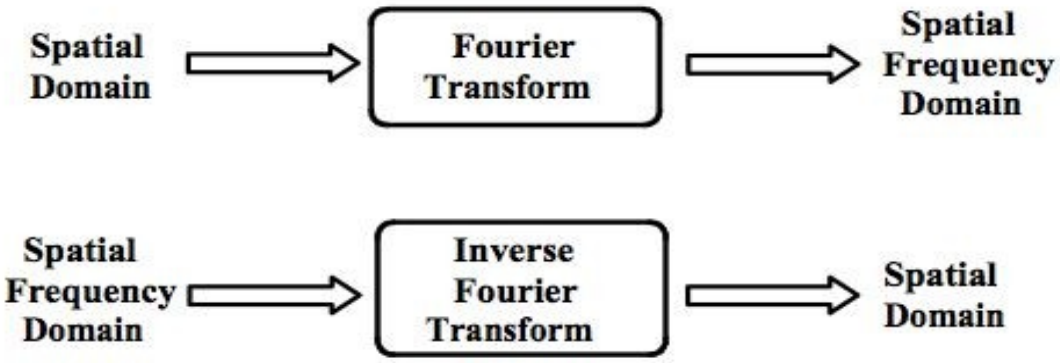

Figure 2-19. Fourier transform convert image data (Maher et al, 2006)

Illustration of the use of the Fourier Transform; The FT and its inverse allow us to convert image data from the spatial to spatial frequency domains and vice versa, respectively. A more complicated 2-D Fourier spectrum is obtained when a chest radiograph is transformed to the spatial frequency domain as illustrated in the next figure. The transformed data show a broad range of spatial frequencies, with significant vertical and horizontal features, as might be expected from the horizontal ribs and vertical vertebral column displayed in the radiograph (Gorman et al, 2008).

2.8. Images in MATLAB and the Image Processing Toolbox:

MatLab (Matrix Laboratory) is a high performance interactive software package for scientific and engineering computation developed by MathWorks, MatLab allows matrix computation, implementation of algorithms, simulation, plotting of functions and data, signal and image processing by the Image Processing Toolbox. (Mathworks Inc., 2009). The basic data structure in MATLAB is the array, an ordered set of real or complex elements. This object is naturally suited to the representation of images, real-valued, ordered sets of color or intensity data. (MATLAB does not support complex-valued images.) MATLAB stores most images as two-dimensional arrays (i.e., matrices), in which each element of the matrix corresponds to a single pixel in the displayed image. (Pixel is derived from picture element and usually denotes a single dot on a computer display.) For example, an image composed of 200 rows and 300

columns of different colored dots would be stored in MATLAB as a 200-by-300 matrix. Some images, such as RGB, require a three-dimensional array, where the first plane in the third dimension represents the red pixel intensities, the second plane represents the green pixel intensities, and the third plane represents the blue pixel intensities.

MATLAB offers simple functions that can read images of many file formats and supports a number of color maps. Depending on file type and color space, the returned matrix is either a 2D matrix of intensity values (grey scale images) or a 3D matrix of RGB values. Nuclear medicine images are grey scale or true color images (RGB that is Red, Green and Blue) (MathWorks, 2001).

2.8.1. MATLAB image tool:

MATLAB is a comprehensive set of reference-standard algorithms and graphical tools for image processing, analysis, visualisation and algorithm development. It offers the possibility to restore noisy or degraded images, enhance images for improved intelligibility, extract features, analyse shapes and textures, and register two images. Thus, it includes all the functions that MatLab utilises in order to perform any sophisticated analysis needed after the acquisition of an image. Most toolbox functions are written in open MatLab language offering the opportunity to the user to inspect the algorithms, to modify the source code and create custom functions (Wilson et al., 2003, Perutka, 2010). The Image Tool opens by simply writing the command imtool in the main function window. Then a new window opens and the next step is loading an image. In the menu, there are many functions already installed in order to use it as simple image processing software. The tools include image information appearance, image zooming in and out, panning, adjustment of the window level and width, adjustment of contrast, cropping, distance measurement,

conversion of the image to a pixel matrix and color map choices (grey scale, bone color, hot regions among others). These are the most common functions likely to be performed in the initial processing approach. Moreover, the user can make some further manipulations such as 3D rotation to respective 3D images and plotting of pixel data (Lyra, et al, 2011).

2.8.2. Image processing techniques with MATLAB:

Include all the possible tools used to change or analyze images.

2.8.2.1. Contrast enhancement:

One of the very first image processing issues is the contrast enhancement. The acquired image does not usually present the desired object contrast. The improvement of contrast is absolutely needed as the organ shape, boundaries and internal functionality can be better depicted. In addition, organ delineation can be achieved in many cases without removing the background activity.

The command that implements contrast processing is the ***imadjust***. Using this, the contrast in an image can be enhanced or degraded if needed. Moreover, a very useful result can be the inversion of colors, especially in grey scale images, where an object of interest can be efficiently outlined. The general function that implements contrast enhancement is the following:

J = imadjust(I,[low_in high_in],[low_out high_out],gamma);

While the function for colour inversion is the following:

J = imadjust(I,[0 1],[1 0],gamma); or J = imcomplement(I);

Suppose that ***J***, is the new image, ***I***, is the initial image and gamma factor depicts the shape of the curve that describes the relationship between the values of ***I*** and ***J***. If the gamma factor is omitted, it is considered to be 1.

2.8.2.2. Organ contour:

In many nuclear medicine images, the organs' boundaries are presented unclear due to low resolution or presence of high percentage of noise.

In order to draw the contour of an organ in a nuclear medicine image, the command ***imcontour*** is used. In addition, a variable n defines the number of equally spaced contours required. This variable is strongly related with the intensity of counts. For higher n values, the lines are drawn with smaller spaces in between and depict different streaks of intensity.

2.8.2.3. Image interpolation:

Interpolation is a topic that has been widely used in image processing. It constitutes of the most common procedure in order to resample an image, to generate a new image based on the pattern of an existing one. Moreover, re-sampling is usually required in medical image processing in order to enhance the image quality or to retrieve lost information after compression of an image (Lehmann et al., 1999).

The interpolation process, these options include the resizing of an image according to a defined scaling factor, the choice of the interpolation type and the choice of low-pass filter. The general command that performs image resizing is imresize. However, the way that the whole function has to be written depends heavily on the characteristics of the new image. The size of the image can be defined as a scaling factor of the existing image or by exact number of pixels in rows and columns. Spatial interpolation techniques here the pixel values of unknown pixels are estimated using the pixel values of known neighbouring pixels. Suppose the image above is zoomed again and suppose that this time the known pixels are distributed to the corners of the zoomed image (Lyra, et al, 2011).

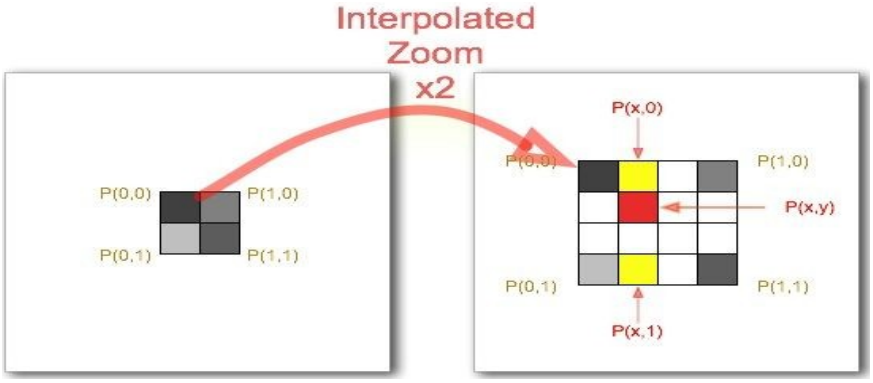

Figure 2-20. Interpolation applied to zooming an image by a factor of two (Maher et al, 2006)

2.8.2.4. Filtering in MATLAB:

In MATLAB, using Image Processing Toolbox we can design and implemented filters for image data. For linear filtering, MATLAB provides the ***fspecial*** command to generate some predefined common 2D filters.

h=fspecial(filtername, parameters)

The ***filtername*** is one of the average, disk, gaussian, laplacian, log, motion, prewitt, sobel and unsharp filters; that is the parameters related to the specific filters that are used each time. Filters are applied to 2D images using the function filter2 with the syntax:

Y = filter2(h,X)

The function ***filter2*** filters the data in matrix ***X*** with the filter h. For multidimensional images the function ***imfilter*** is used.

B = imfilter(A,h)

This function filters the multidimensional array ***A*** with the multidimensional filter ***h.*** ***imfilter*** function is more general than ***filter2*** function. For nonlinear filtering in MatLab the function ***nlfilter*** is applied, requiring three arguments: the input image, the size of the filter and the function to be used. ***B = nlfilter(A, [m n], fun)***

Figure below presents different implementations of the mean filter on a kidneys image with filters 3x3, 9x9, 15x15, 20x20 and 25x25. As it can be easily noticed, the mean filter balances and smoothes the image, flattening the differences. The filtered images do not present edges at the same extent as in the original one. For larger kernel size, the blurring of the image is more intense. Image smoothening can be used in several areas of nuclear medicine and can serve in different points of view of the examined organ.

To remove impulse noise from a SPECT slice, for example in a renal study, for this reason we mix the image with impulse noise (salt and pepper). The image has a 512×512 matrix size and grey levels between 0 and 255. The most suitable filter for removing impulse noise is the median filter. Because it is a nonlinear filter, the command ***nlfilter*** is now used (Lyra, et al, 2011).

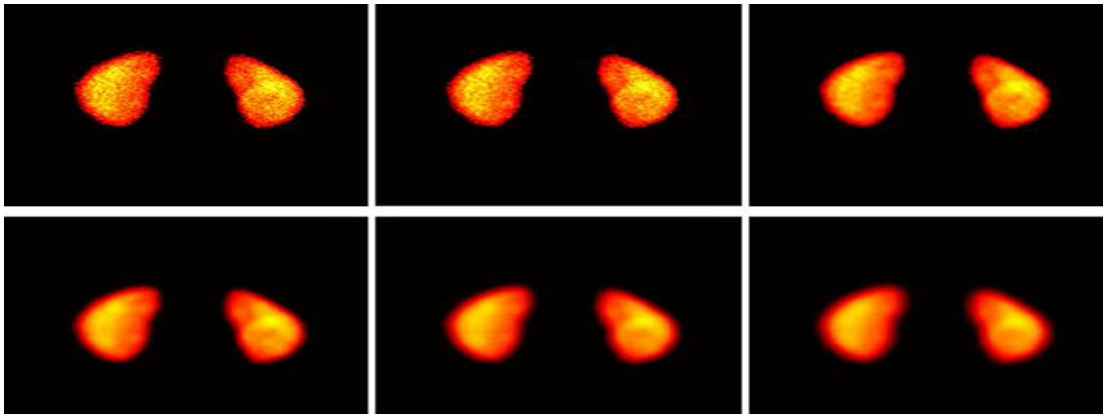

Figure 2-21. Mean filter applied on kidneys image (a) Original image, (b) average filter 3x3, (c) average filter 9x9, (d) average filter 15x15, (e) average filter 20x20 and, (f) average filter 25x25 [(a) to (f) from left to right] (Lyra, et al, 2011)

```
I = imread('kidneys.tif');

figure, imshow(I);

J = imnoise(I,'salt & pepper',0.05);

figure, imshow(J);

fun = @(x) median(x(:));
```

K = nlfilter(J,[3 3],fun);

figure, imshow(K);

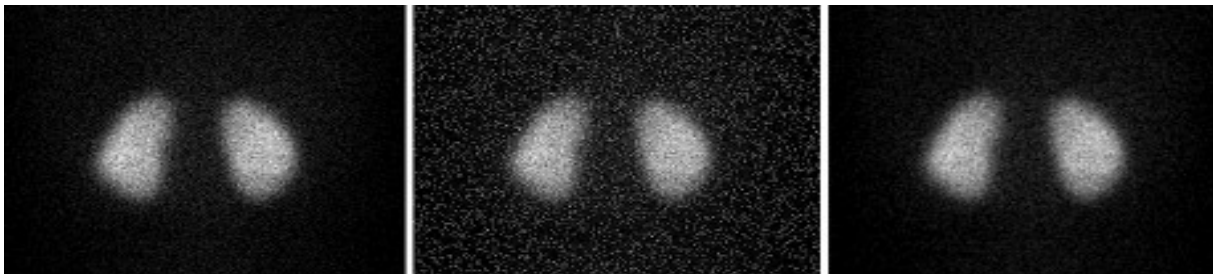

Figure 2-22. Impulse noise elimination by median filter (a) Original image (b) the image with impulse noise (c) the image on which the noise is suppressed with the median filter. [(a) to (c) from left to right] (Lyra, et al, 2011)

Can be very useful in the nuclear medicine examinations of parenchymatous organs (liver, lungs, thyroid or kidneys) as it consists of a simple enough method for the reduction of noise which interferes in the image due to the construction of electronic circuits (Lyra, et al, 2011).

2.8.2.5. Image segmentation:

The image segmentation describes the process through which an image is divided into constituent parts, regions or objects in order to isolate and study separately areas of special interest. This process assists in detecting critical parts of a nuclear medicine image that are not easily displayed in the original image. The process of segmentation has been developed based on lots of intentions such as delineating an object in a gradient image, defining the region of interest or separating convex components in distance-transformed images. Attention should be spent in order to avoid ‘over-segmentation’ or ‘under-segmentation’. In nuclear medicine, segmentation techniques are used to detect the extent of a tissue, an organ, a tumour inside an image, the boundaries of structures in cases that these are ambiguous and the areas that radiopharmaceutical concentrate in a greater extent. Thus, the segmentation process

serves in assisting the implementation of other procedures; in other words, it constitutes the fundamental step of some basic medical image processing.

There are two ways of image segmentation: based on the discontinuities and based on the similarities of structures inside an image. In nuclear medicine images, the discontinuity segmentation type finds more applications. This type depends on the detection of discontinuities or else, edges, inside the image using a threshold. The implementation of threshold helps in two main issues:

- The removal of unnecessary information from the image (background activity).
- The appearance of details not easily detected.

The edge detection uses the command edge. In addition, a threshold is applied in order to detect edges above defined grey-scale intensity. Also, different methods of edge detection can be applied according to the filter each of them utilises. The most useful methods in nuclear medicine are the ‘Sobel’, ‘Prewitt’, ‘Roberts’, ‘Canny’ as well as ‘Laplacian of Gaussian'. It is noted that the image is immediately transformed into a binary image and edges are detected. The general function used for the edge detection is the following: [BW] = edge (image, ‘method’, threshold): Where [BW] is the new binary image produced, image is the initial one; ‘method’ refers to the method of edge detection and ‘threshold’ to the threshold applied. In nuclear medicine, the methods that find wide application are the sorbel, prewitt and canny another application of segmentation in nuclear medicine is the use of gradient magnitude. The original image is loaded then the edge detection method of sobel is applied in accordance with a gradient magnitude which gives higher regions with higher grey-scale intensity.

2.8. 2.6. Background activity removal:

One of the first steps to be completed in the medical image processing is removing the background activity. This procedure is based on image segmentation as in order to achieve the background activity removal, the organs' boundaries are first defined. The steps in this procedure are the following:

- The image is read.
- The image is appeared.
- A grey level threshold is decided by MATLAB.
- The image is transformed into binary image in order to isolate the organ.
- The binary image is multiplied by the initial one.
- The final image is appeared.
- The color can change (or not) according to individuals' needs.

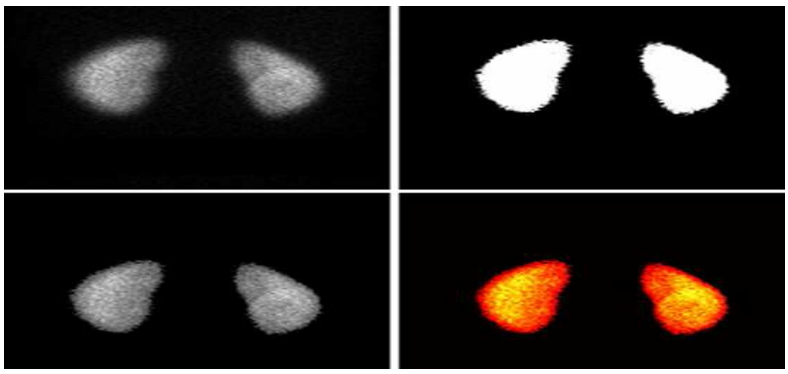

Figure 2-23. Background subtraction: (a) Original image, (b) segmented binary image after thresholding depicting only sharp organ boundaries, (c) image after background removal, (d) change of colour to nuclear medicine pattern. [(a) to (d) from left to right] (Lyra, et al, 2011)

2.8.2.7. MATLAB mesh plot:

The surface plot or the mesh plot can be used in order to extract information about the consistency of an organ or the loss of functionality. In order to construct a surface plot

from a striatum image, the series of images that include the highest level of information was selected. (Lyra et al 2010b).

2.8.2.8. Intensity volume and 3-D visualization:

Volume visualisation in nuclear medicine consists of a method for extracting information from volumetric data utilising and processing a nuclear medicine image (Lyra et al., 2010b). In MatLab, this can be achieved by constructing a 3D surface plot which uses the pixel identities for (x, y) axes and the pixel value is transformed into surface plot height and, consequently, colour. Apart from that, 3D voxel images can be constructed; image projections are acquired, iso-contours are depicted on them including a number of voxels and, finally all of them can be added in order to create the desirable volume image. The size of the re-projection is the same as the main size of input image. (Lyra et al.,2010a).

2.8.2.9. Image registration:

Is used for aligning two images of the same object into a common coordinate system presenting the fused image, The images can be acquired from different angles, at different times, by different or same modalities. A typical example is the combination of SPECT and CT images or PET and CT, Image registration is used mainly for two reasons: i) to obtain enhanced information and details from the image for more accurate diagnosis or therapy (Li & Miller, 2010) and, ii) to compare patient's data (Zitova & Flusser, 2003). MatLab can be used in order to perform such a process. The whole procedure shall follow a specific order. The first step of the procedure includes the image acquisition and enhancements in brightness and contrast. The next step includes the foundation of a spatial transformation between the two images. The final step in image registration is the overlapping of the two images allowing a suitable

level of transparency. A new image is created containing information from both pictures from which, the first has been produced (Delbeke et al., 2009).

Chapter Three

Materials and Methods

3.1. Materials:

3.1.1. Equipments:

- Personal Computer (PC)
- MatLab program version R2009a (9.0.2.1.0)
- Gamma camera

3.2. Study Duration:

This study proposed to be carried between September 2014 to January 2015.

3.2.1.Study Place:

The proposed study was conducted in Elnileen Center for Nuclear Medicine, College of Medical Radiological Science, Sudan University of Science and Technology

3.2.2. Study Sample :

The totals of number of patients in this study were 10 patients.

3.3. Methods of data collection:

Image enhancement technique:

1.Contrast-limited adaptive histogram equalization (CLAHE):

This technique used to enhance the contrast of the grayscale image (bone scan) by transforming the values using contrast-limited adaptive histogram equalization ***(CLAHE). CLAHE*** operated on small regions in the image, called ***tiles***, rather than the entire image, each tile's contrast was enhanced, so that the histogram of the output region approximately matches the histogram specified by the 'Distribution' parameter. The neighboring tiles were then combined using bilinear interpolation to eliminate artificially induced boundaries. The contrast, especially in homogeneous areas, could be limited to avoid amplifying any noise that might be present in the image.

J = ***adapthisteq***(***I***) enhanced the contrast of the grayscale image ***I*** by transforming the values using contrast-limited adaptive histogram equalization ***(CLAHE).***

2.Enhance contrast using histogram equalization:

This programming code ***(histeq)*** enhanced the contrast of images (bone scan) by transforming the values in an intensity image, or the values in the ***colormap*** of an indexed image, so that the histogram of the output image approximately matched a specified histogram. ***J = histeq(I, hgram)*** transformed the intensity image ***I*** so that the histogram of the output intensity image ***J*** with length***(hgram)*** bins approximately matches ***hgram***. The vector ***hgram*** should contain integer counts for equally spaced bins with intensity values in the appropriate range: ***[0, 1]*** for images of class double, ***[0, 255]*** for images of class ***uint8***, and ***[0, 65535]*** for images of class ***uint16***. ***histeq*** automatically scales ***hgram*** so that ***sum(hgram) = prod(size(I)).*** The histogram of ***J*** was better match ***hgram*** when ***length (hgram)*** is much smaller than the number of discrete levels in ***I***.

J = histeq(I, n) transforms the intensity image ***I***, returning in ***J*** an intensity image with ***n*** discrete gray levels. A roughly equal number of pixels were mapped to each of

the ***n*** levels in ***J***, so that the histogram of ***J*** is approximately flat. (The histogram of ***J*** was flatter when ***n*** was much smaller than the number of discrete levels in ***I***) The default value for n is 64. ***[J, T] = histeq(I,...)*** returns the grayscale transformation that maps gray levels in the image ***I*** to gray levels in ***J***.

newmap = histeq(X, map, hgram) transforms the ***colormap*** associated with the indexed image ***X*** so that the histogram of the gray component of the indexed image ***(X,newmap)*** approximately matches ***hgram***. The ***histeq*** function returns the transformed ***colormap*** in ***newmap***. ***length(hgram)*** must be the same as size***(map,1).*** ***newmap = histeq(X, map)*** transforms the values in the ***colormap*** so that the histogram of the gray component of the indexed image ***X*** is approximately flat. It returns the transformed ***colormap*** in ***newmap. [newmap, T] = histeq(X,...)*** returns the grayscale transformation ***T*** that maps the gray component of map to the gray component of ***newmap.***

3.Adjust image intensity values or colormap:

This programming code ***(imadjust)*** used to enhance the images of bone scan by increased of contract of the image , ***J = imadjust(I)*** mapped the intensity values in grayscale image ***I*** to new values in ***J*** such that ***1%*** of data is saturated at low and high intensities of ***I***. This increased the contrast of the output image ***J***. This syntax was equivalent to ***imadjust(I,stretchlim(I))***. ***J = imadjust(I,[low_in; high_in],[low_out; high_out])*** maps the values in ***I*** to new values in ***J*** such that values between ***low_in*** and ***high_in*** map to values between ***low_out*** and ***high_out***. Values below ***low_in*** and above ***high_in*** were clipped; that is, values below ***low_in*** map to ***low_out***, and those above ***high_in*** map to ***high_out***. Could use an empty matrix ***([])*** for ***[low_in high_in]*** or for ***[low_out high_out]*** to specify the default of ***[0 1].***

J = imadjust(I,[low_in; high_in],[low_out; high_out],gamma) maps the values in ***I*** to new values in ***J***, where ***gamma*** specifies the shape of the curve describing the relationship between the values in ***I*** and ***J***. If ***gamma*** was less than ***1***, the mapping was weighted toward higher (brighter) output values. If ***gamma*** was greater than ***1***, the mapping was weighted toward lower (darker) output values. If omitted the argument, ***gamma*** defaults to ***1*** (linear mapping). ***newmap = imadjust(map,[low_in; high_in],[low_out; high_out],gamma)*** transforms the ***colormap*** associated with an indexed image. If ***low_in***, ***high_in***, ***low_out***, ***high_out,*** and ***gamma*** were scalars, then the same mapping applies to red, green, and blue components. Unique mappings for each color component are possible when ***low_in*** and ***high_in*** are both 1-by-3 vectors. ***low_out*** and ***high_out*** are both 1-by-3 vectors, or ***gamma*** was a 1-by-3 vector. The rescaled ***colormap newmap*** was the same size as ***map***.

RGB2 = imadjust(RGB1,...) performs the adjustment on each image plane (red, green, and blue) of the ***RGB*** image ***RGB1***. As with the ***colormap adjustment***, could apply unique mappings to each plane.

4.2-D median filtering:

Median filtering was a nonlinear operation often used in image processing to reduce ***"salt and pepper"*** noise from the images (bone scan). A median filter was more effective than convolution when the goal was to simultaneously reduce noise and preserve edges.

B = medfilt2(A, [m n]) performs median filtering of the matrix ***A*** in two dimensions. Each output pixel contains the median value in the ***m***-by-n neighborhood around the corresponding pixel in the input image. ***medfilt2*** pads the image with ***0s*** on the edges, so the median values for the points within ***[m n]/2*** of the edges might appear distorted.

B* = *medfilt2(A) performs median filtering of the matrix ***A*** using the default 3-by-3 neighborhood. ***B* = *medfilt2(A, 'indexed', ...)*** processes ***A*** as an indexed image, padding with ***0s*** if the class of A is ***uint8***, or ***1s*** if the class of ***A*** is ***double***. ***B* = *medfilt2(..., padopt)*** controls how the matrix boundaries were padded. ***padopt*** may be ***'zeros'*** (the default), ***'symmetric'***, or ***'indexed'***. If padopt is ***'symmetric', A*** was symmetrically extended at the boundaries. If ***padopt*** is ***'indexed'***, ***A*** was padded with ones if it was ***double***; otherwise it was padded with ***zeros***.

5.contrast stretch image:

This programming code used to enhance of the images (bone scan), ***LOW_HIGH = stretchlim(I)*** returns ***LOW_HIGH***, a two-element vector of pixel values that specify lower and upper limits that can be used for contrast stretching image ***I***. By default, values in ***LOW_HIGH*** specify the bottom ***1%*** and the top ***1%*** of all pixel values. The gray values returned can be used by the ***imadjust*** function to increase the contrast of an image.

LOW_HIGH = stretchlim(I, TOL) where ***TOL*** is a two-element vector ***[LOW_FRACT HIGH_FRACT]*** that specifies the fraction of the image to saturate at low and high pixel values. If ***TOL*** is a scalar, ***LOW_FRACT = TOL***, and ***HIGH_FRACT = 1 - LOW_FRACT***, which saturates equal fractions at low and high pixel values. If you omit the argument, ***TOL*** defaults to ***[0.01 0.99],*** saturating ***2%.*** If ***TOL = 0, LOW_HIGH = [min(I(:)); max(I(:))]. LOW_HIGH = stretchlim(RGB, TOL)*** returns a 2-by-3 matrix of intensity pairs to saturate each plane of the ***RGB*** image. ***TOL*** specifies the same fractions of saturation for each plane.

Chapter Four

The Results

4.1. Result of bone scan image number (1):

1.Contrast-limited adaptive histogram equalization (CLAHE)

Step one: image reading as shown in figure 4-1:

I= imread ('bonescan.jpg');

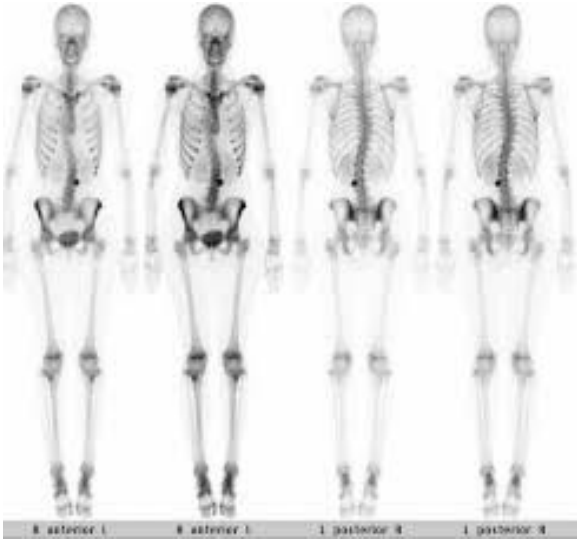

Figure 4-1. The original bone scan image test (A1)

Step two: Convert indexed image to true-color (RGB) format

RGB = ind2rgb(I);

Step three: Convert image to L*a*b* color space

cform2lab = makecform('srgb2lab');

LAB = applycform(RGB, cform2lab);

Step four: Scale values to range from 0 to 1

L = LAB(:,:,1)/100;

Step five: Perform CLAHE

LAB(:,:,1) = adapthisteq(L,'NumTiles',...

[8 8],'ClipLimit',0.005)*100;

Step Six: Display the results with image histogram as shown in figure 4-2

figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)

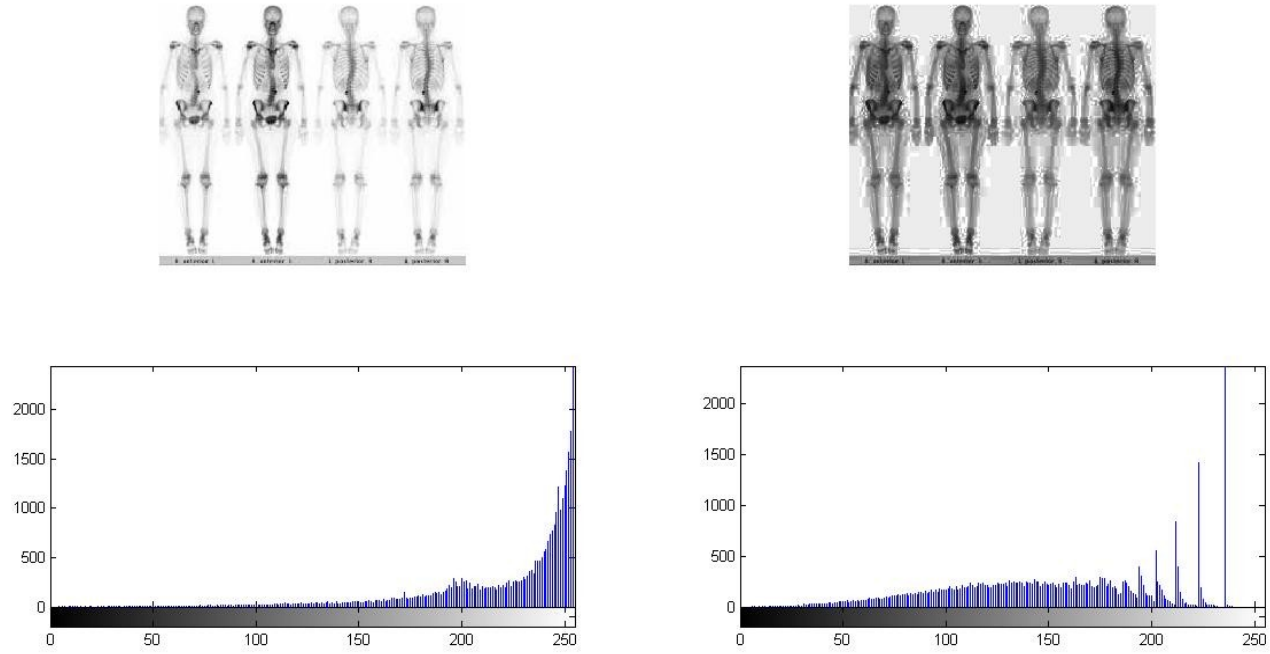

Figure 4-2. CLAHE technique; at left side the original image with histogram and at right side the enhanced image using CLAHE technique from test (A1)

2. Enhance contrast using histogram equalization:

Step one: image reading as shown in figure 4-3:

I= imread ('bonescan.jpg');

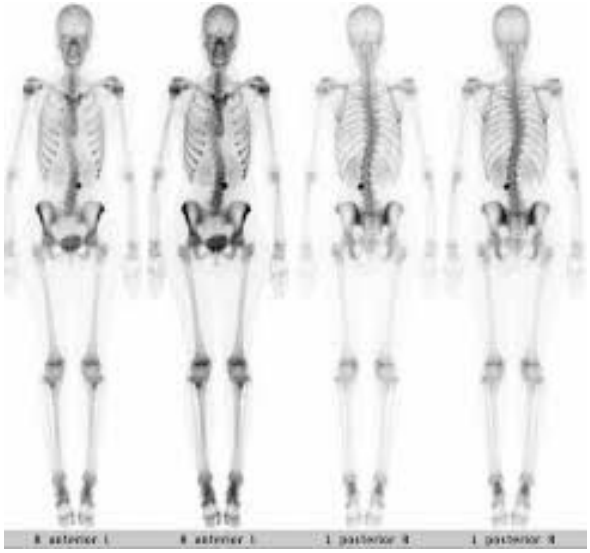

Figure 4-3. The original bone scan image test (A2)

Step two: Convert indexed image to true-color (RGB) format

RGB = ind2rgb(I);

Step three: Convert image to L*a*b* color space

cform2lab = makecform('srgb2lab');

LAB = applycform(RGB, cform2lab);

Step four: Scale values to range from 0 to 1

L = LAB(:,:,1)/100;

Step five: used histogram equalization code.

J = histeq(I);

Step Six: Display the results with image histogram as shown in figure 4-4

figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)

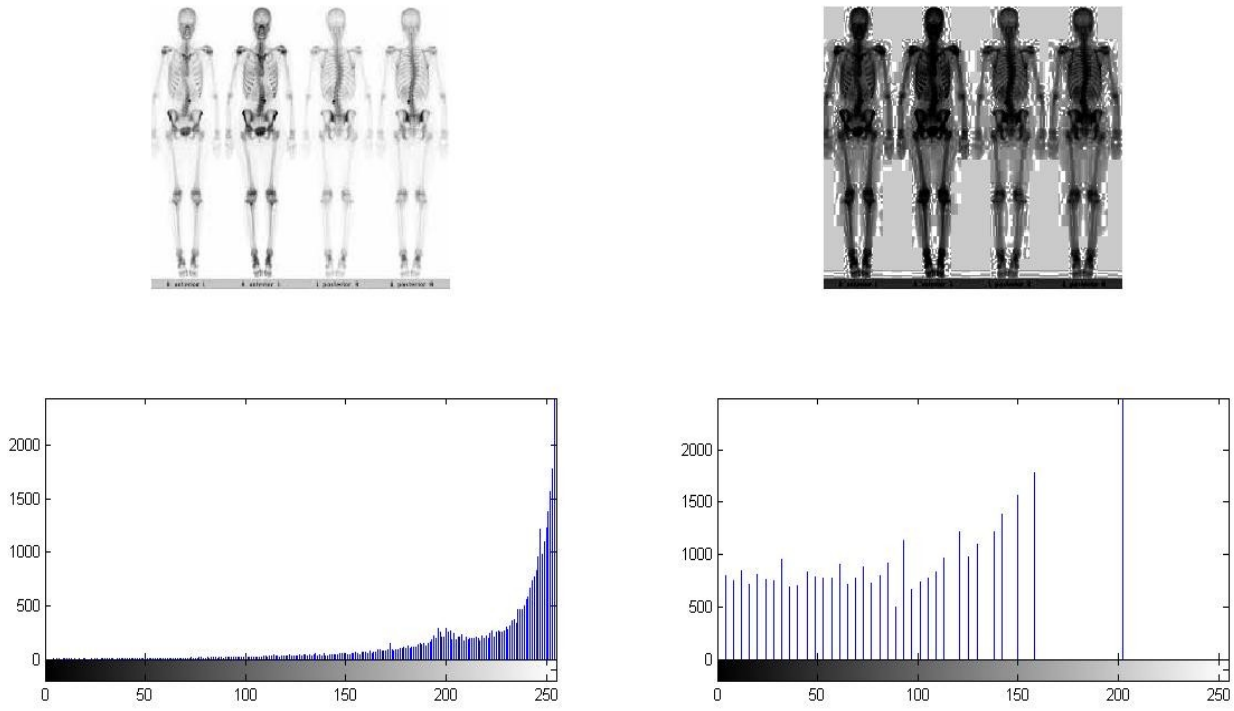

Figure 4-4. histogram equalization technique; at left side the original image with histogram and at right side the enhanced image using histogram equalization technique from test (A2)

3.Adjust image intensity values or colormap:

Step one: image reading as shown in figure 4-5:

I= imread ('bonescan.jpg');

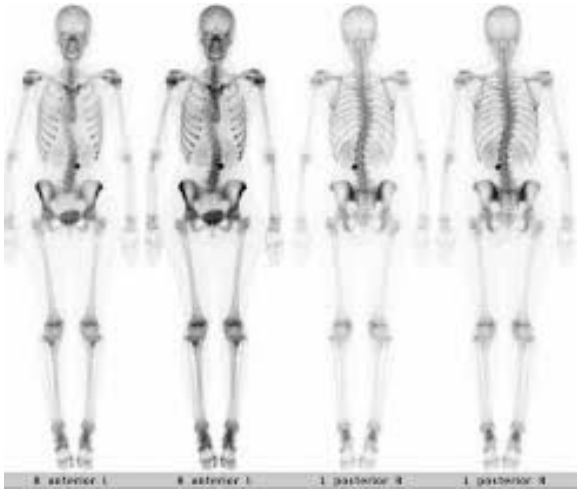

Figure 4-5. The original bone scan image test(A3)

Step two: Convert indexed image to true-color (RGB) format

RGB = ind2rgb(I);

Step three: Convert image to L*a*b* color space

cform2lab = makecform('srgb2lab');

LAB = applycform(RGB, cform2lab);

Step four: Scale values to range from 0 to 1

L = LAB(:,:,1)/100;

Step five: Perform Adjust code**.**

J = imadjust(I);

Step Six: Display the results with image histogram as shown in figure 4-6

figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)

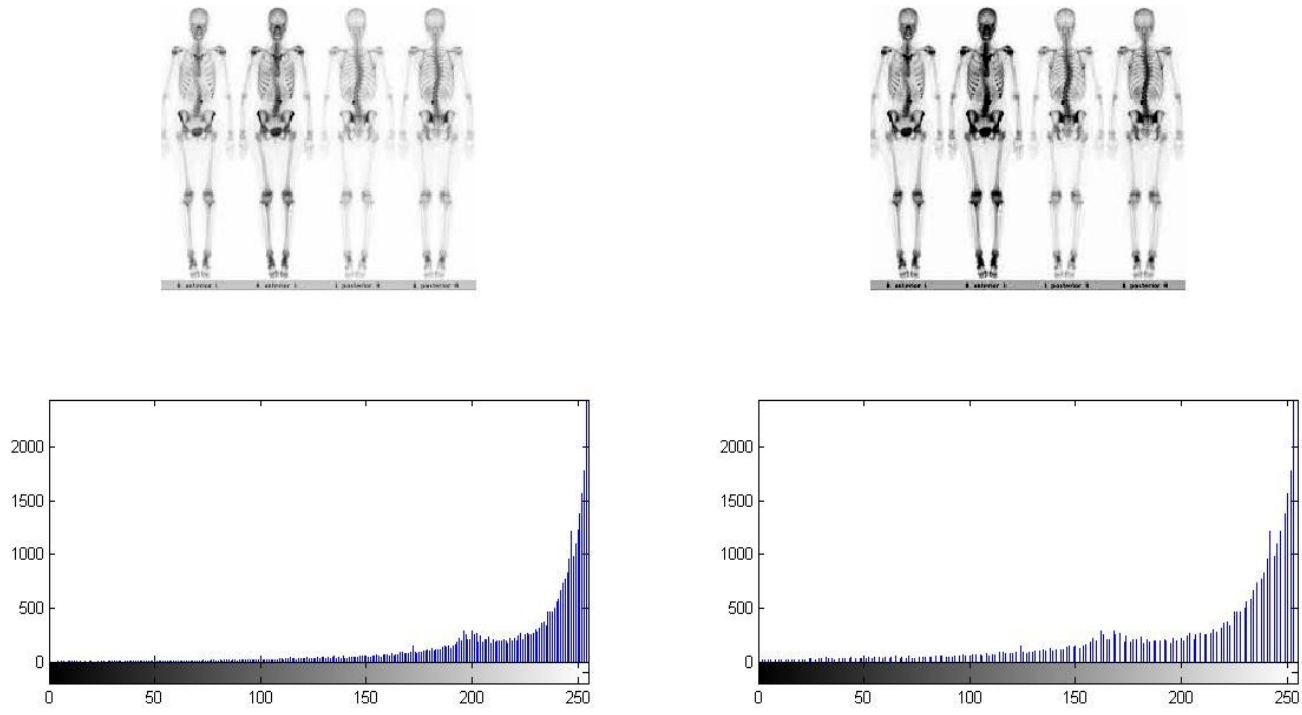

Figure 4-6. Adjust technique; at left side the original image with histogram and at right side the enhanced image using Adjust technique from test (A3)

4.2-D median filtering:

Step one: image reading as shown in figure 4-7:

I= imread ('bonescan.jpg');

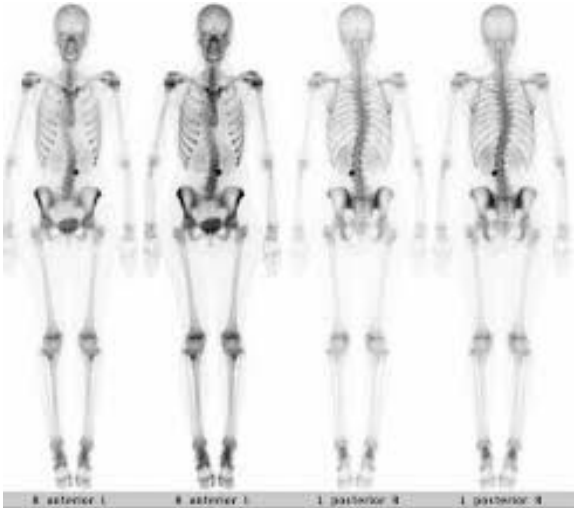

Figure 4-7. The original bone scan image test (A4)

Step two: Convert indexed image to true-color (RGB) format

RGB = ind2rgb(I);

Step three: Convert image to L*a*b* color space

cform2lab = makecform('srgb2lab');

LAB = applycform(RGB, cform2lab);

Step four: Scale values to range from 0 to 1

L = LAB(:,:,1)/100;

Step five: used 2-D median filtering.

J = imnoise(I,'salt & pepper',0.02);

K = medfilt2(J);

Step Six: Display the results with image histogram as shown in figure 4-8

figure, imshow(J)

figure, imshow(K)

figure, imhist(J)

figure, imhist(K)

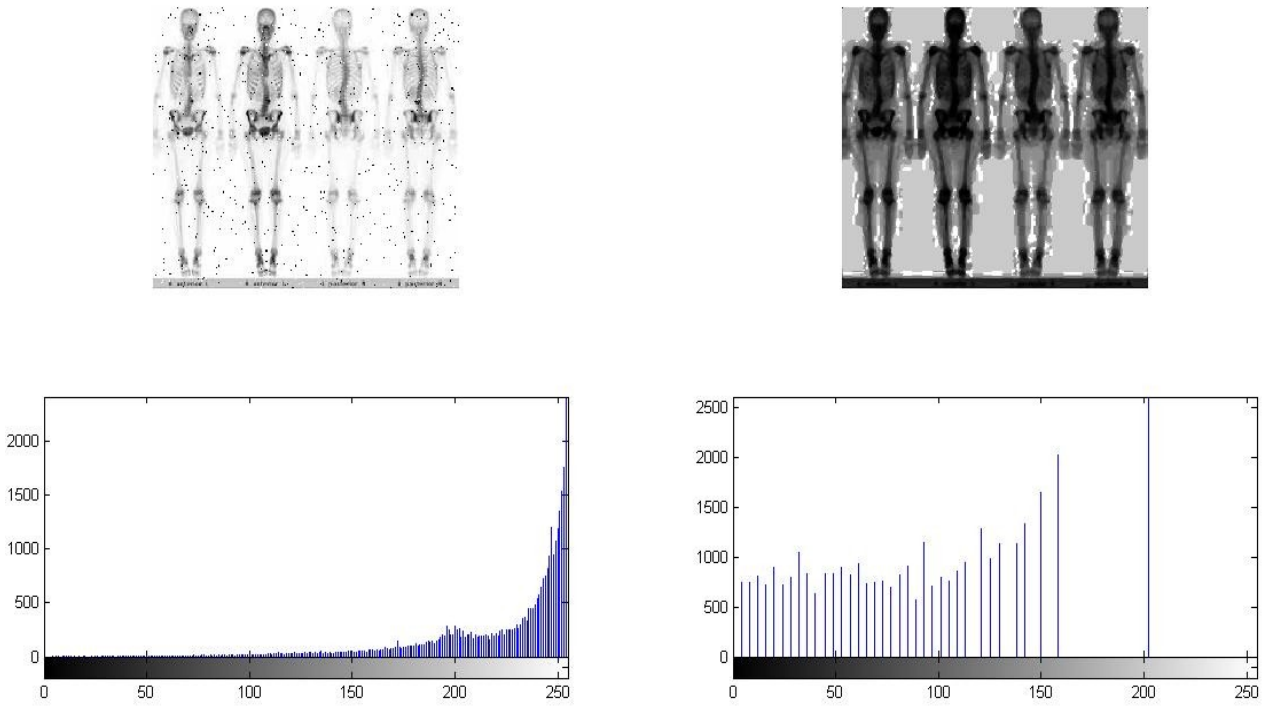

Figure 4-8. 2-D median filtering technique; at left side the blurring image with histogram and at right side the enhanced image using 2-D median filtering technique from test (A4)

5.contrast stretch image:

Step one: image reading as shown in figure 4-9:

I= imread ('bonescan.jpg');

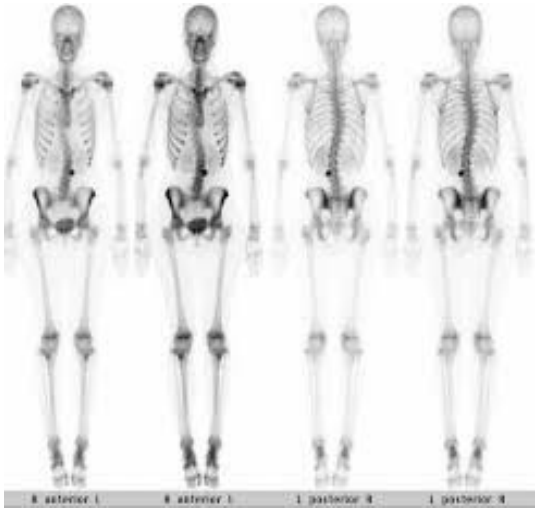

Figure 4-9. The original bone scan image test (A5)

Step two: Convert indexed image to true-color (RGB) format

```
RGB = ind2rgb(I);
```

Step three: Convert image to L*a*b* color space

```
cform2lab = makecform('srgb2lab');
LAB = applycform(RGB, cform2lab);
```

Step four: Scale values to range from 0 to 1

```
L = LAB(:,:,1)/100;
```

Step five: used contrast stretch image code.

```
J = imadjust(I,stretchlim(I),[]);
```

Step Six: Display the results with image histogram as shown in figure 4-10

```
figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)
```

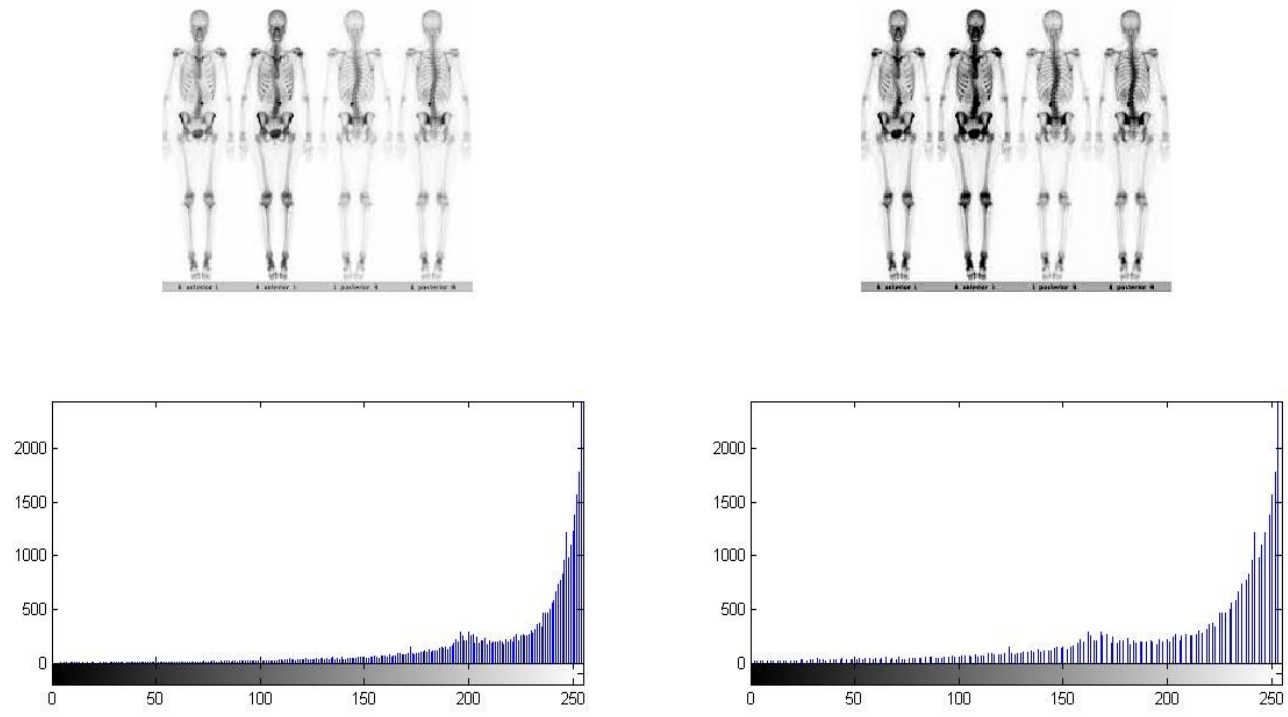

Figure 4-10. Contrast stretch image technique; at left side the original image with histogram and at right side the enhanced image using contrast stretch image technique from test (A5)

4.2. Result of bone scan image number (2):

1.Contrast-limited adaptive histogram equalization (CLAHE)

Step one: image reading as shown in figure 4-11:

I= imread ('bonescan.jpg');

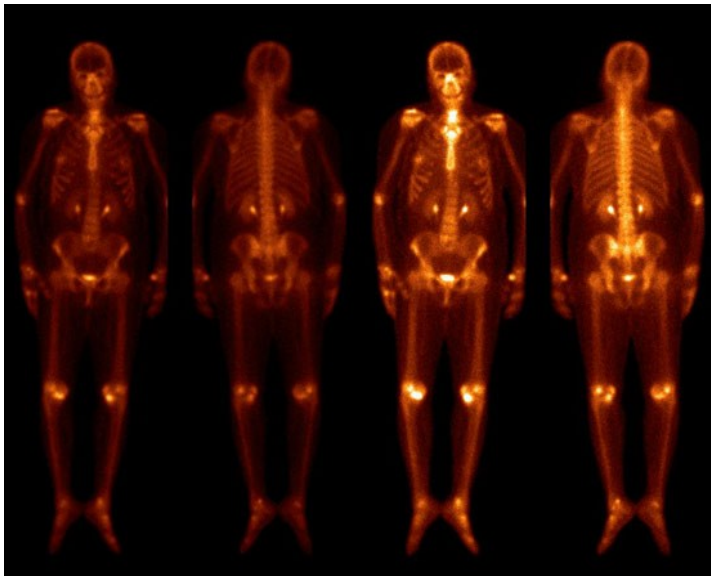

Figure 4-11. The original bone scan image test (B1)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: Perform CLAHE

A = adapthisteq(I,'clipLimit',0.02,'Distribution','rayleigh');

Step four: Display the results with image histogram as shown in figure 4-12

figure, imshow(I)

figure, imshow(A)

figure, imhist(I)

figure, imhist(A)

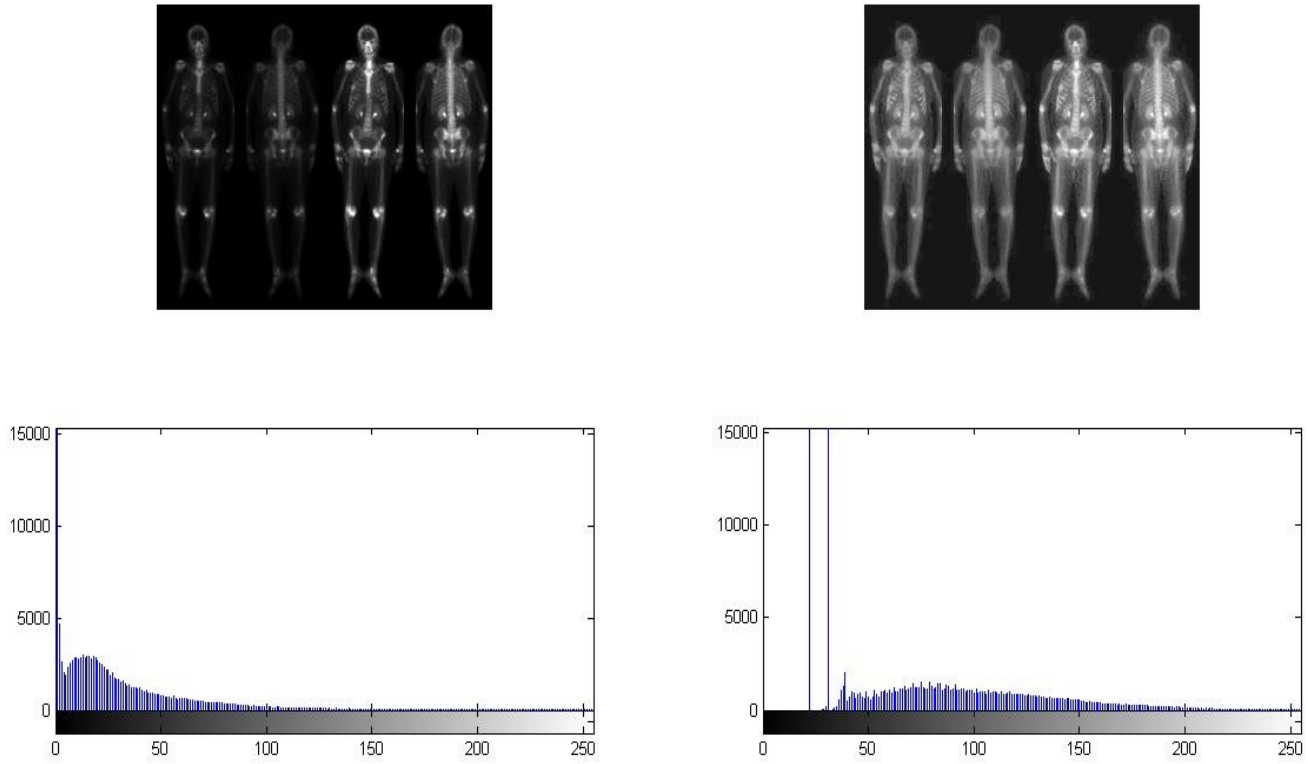

Figure 4-12. CLAHE technique; at left side the gray scale image with histogram and at right side the enhanced image using CLAHE technique from test (B1)

2.Enhance contrast using histogram equalization:

Step one: image reading as shown in figure 4-13:

I= imread ('bonescan.jpg');

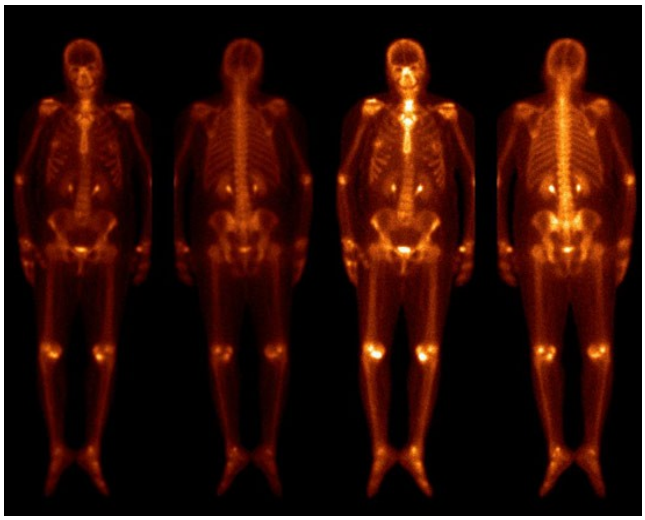

Figure 4-13. The original bone scan image test (B2)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: Perform Adjust code**.**

J = histeq(I);

Step four: Display the results with image histogram as shown in figure 4-14

figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)

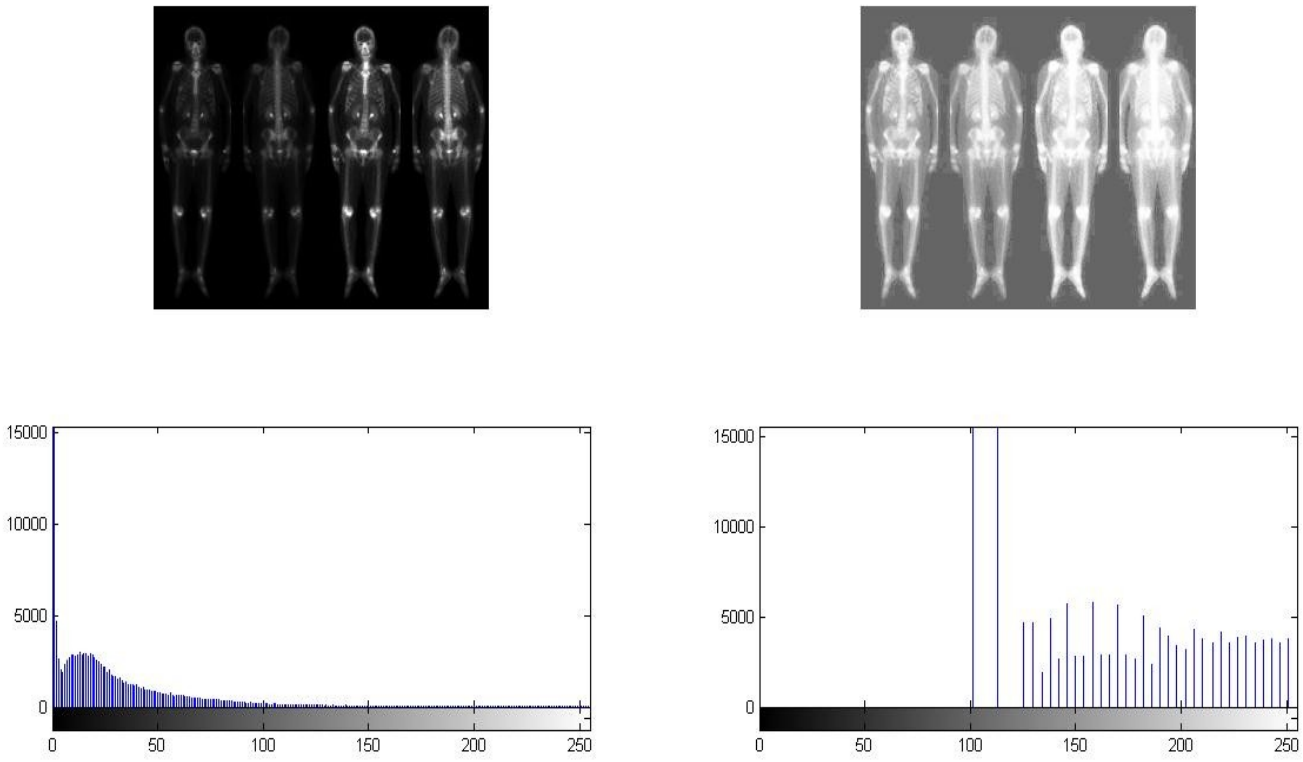

Figure 4-14. histogram equalization technique; at left side the gray scale image with histogram and at right side the enhanced image using histogram equalization technique from test (B2)

3. Adjust image intensity values or colormap:

Step one: image reading as shown in figure 4-15:

I= imread ('bonescan.jpg');

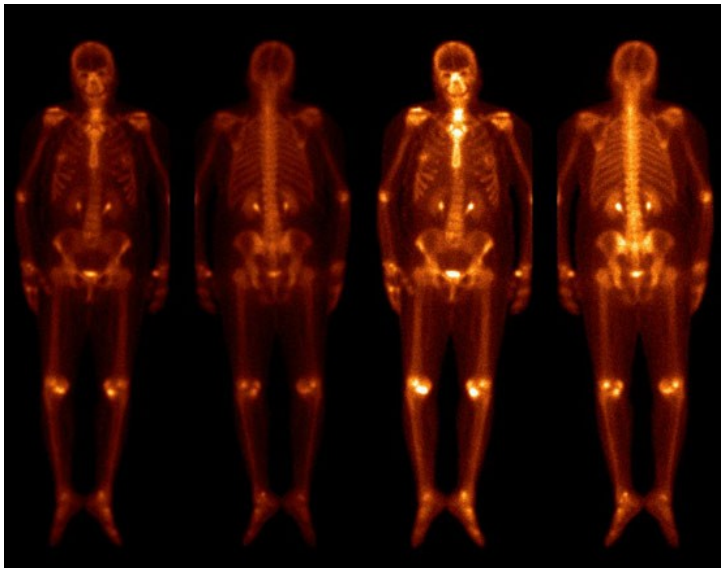

Figure 4-15. The original bone scan image test (B3)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: Perform Adjust code**.**

J = imadjust(I);

Step four: Display the results with image histogram as shown in figure 4-16

figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)

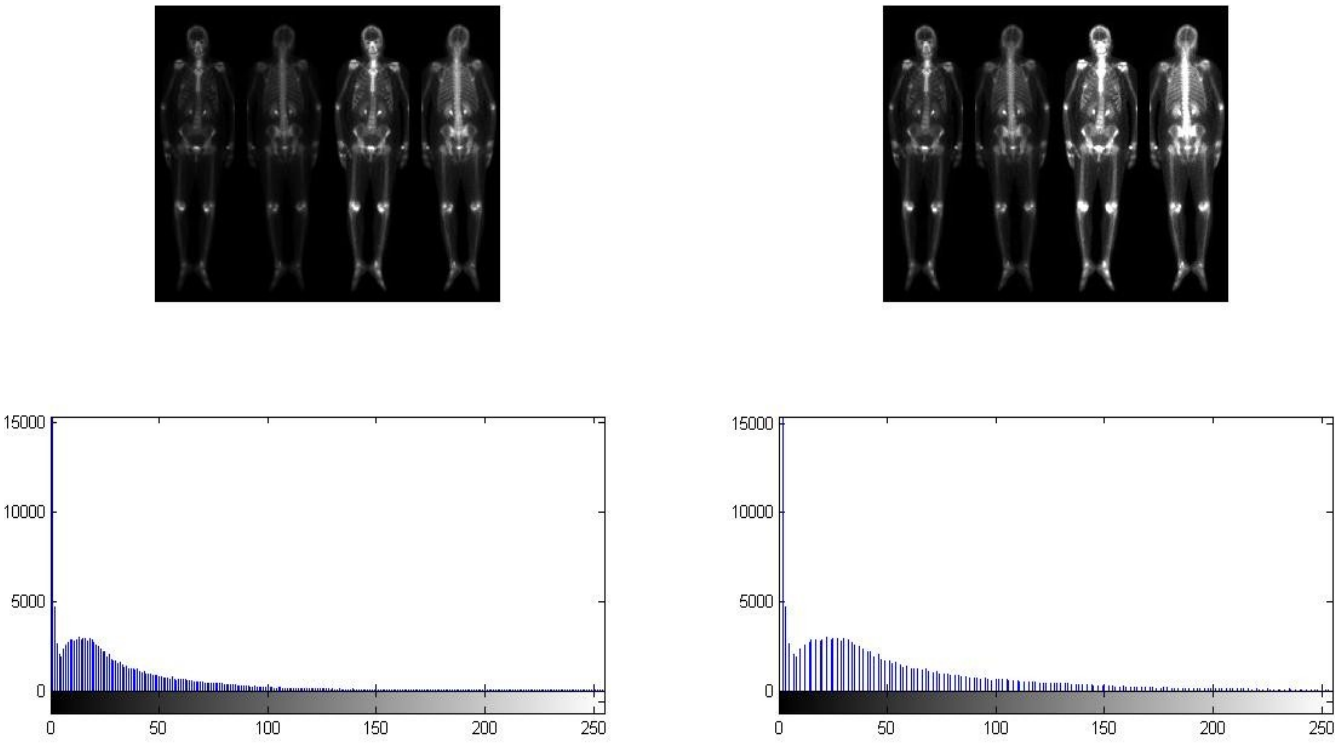

Figure 4-16. Adjust technique; at left side the gray scale image with histogram and at right side the enhanced image using Adjust technique from test (B3)

4.2-D median filtering:

Step one: image reading as shown in figure 4-17:

I= imread ('bonescan.jpg');

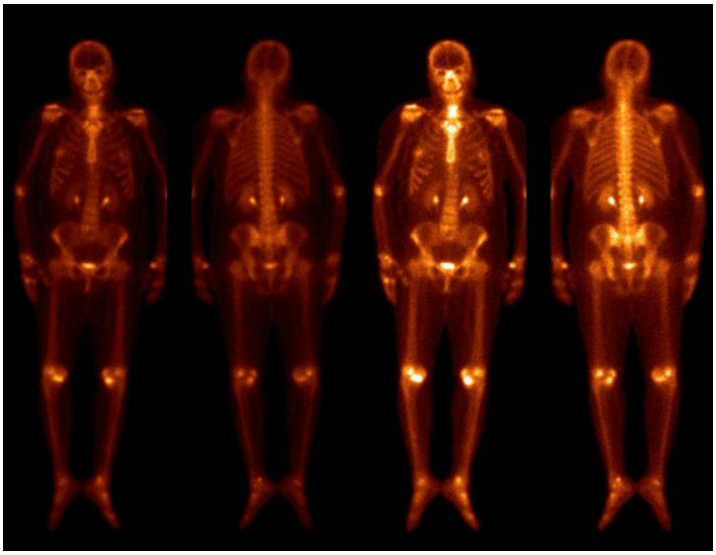

Figure 4-17. The original bone scan image test (B4)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: Perform Adjust code**.**

J = imnoise(I,'salt & pepper',0.02);

K = medfilt2(J);

Step four: Display the results with image histogram as shown in figure 4-18

figure, imshow(J)

figure, imshow(K)

figure, imhist(J)

figure, imhist(K)

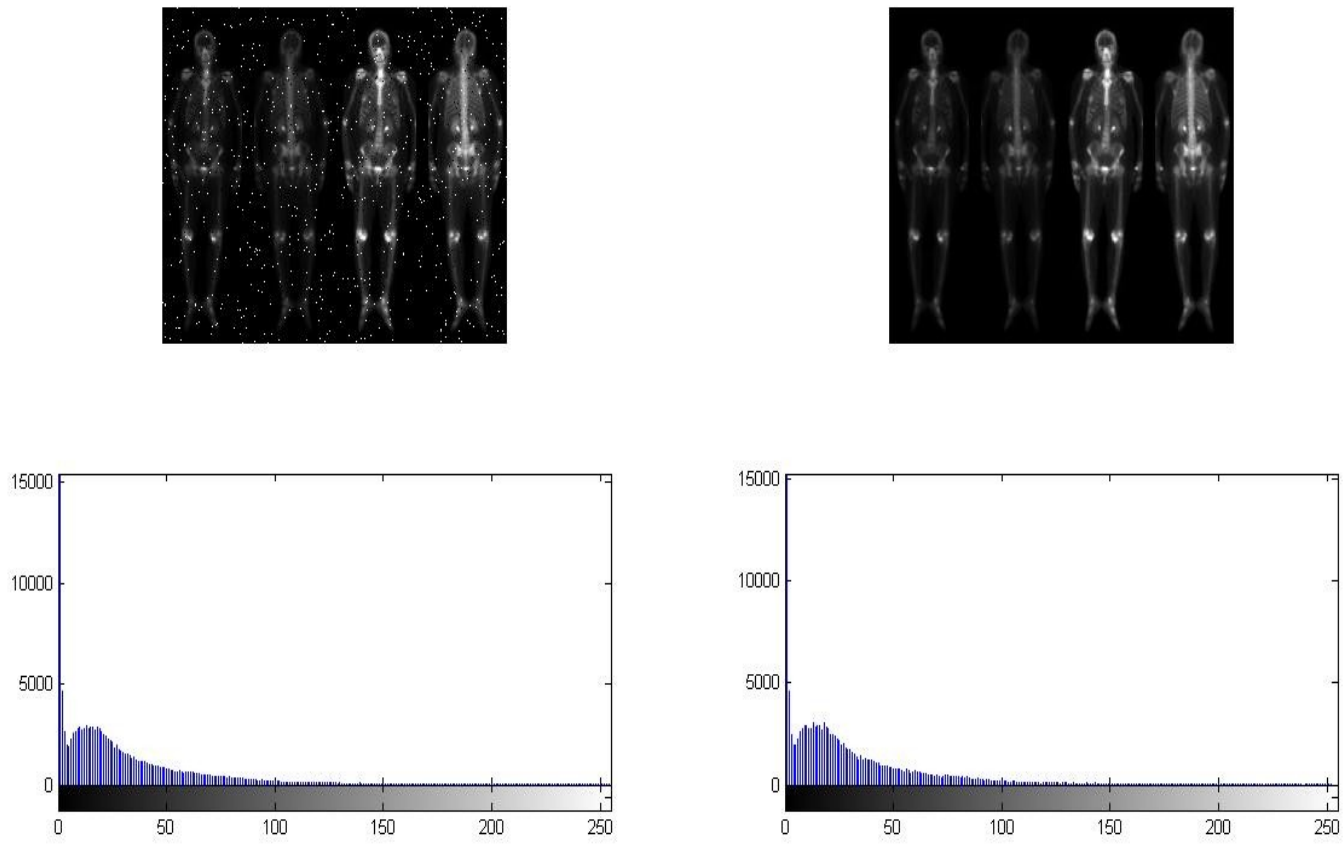

Figure 4-18. 2-D median filtering technique; at left side the blurring image with histogram and at right side the enhanced image using 2-D median filtering technique from test (B4)

5.contrast stretch image:

Step one: image reading as shown in figure 4-19:

I= imread ('bonescan.jpg');

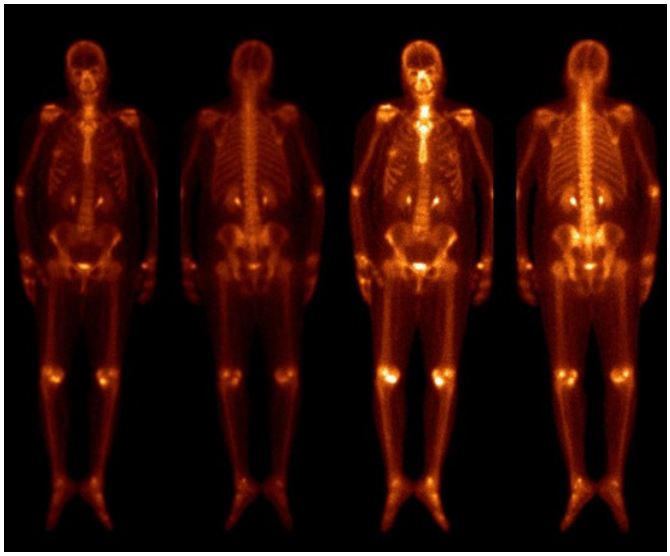

Figure 4-19. The original bone scan image test (B5)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: used contrast stretch image code.

J = imadjust(I,stretchlim(I),[]);

Step four: Display the results with image histogram as shown in figure 4-120

figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)

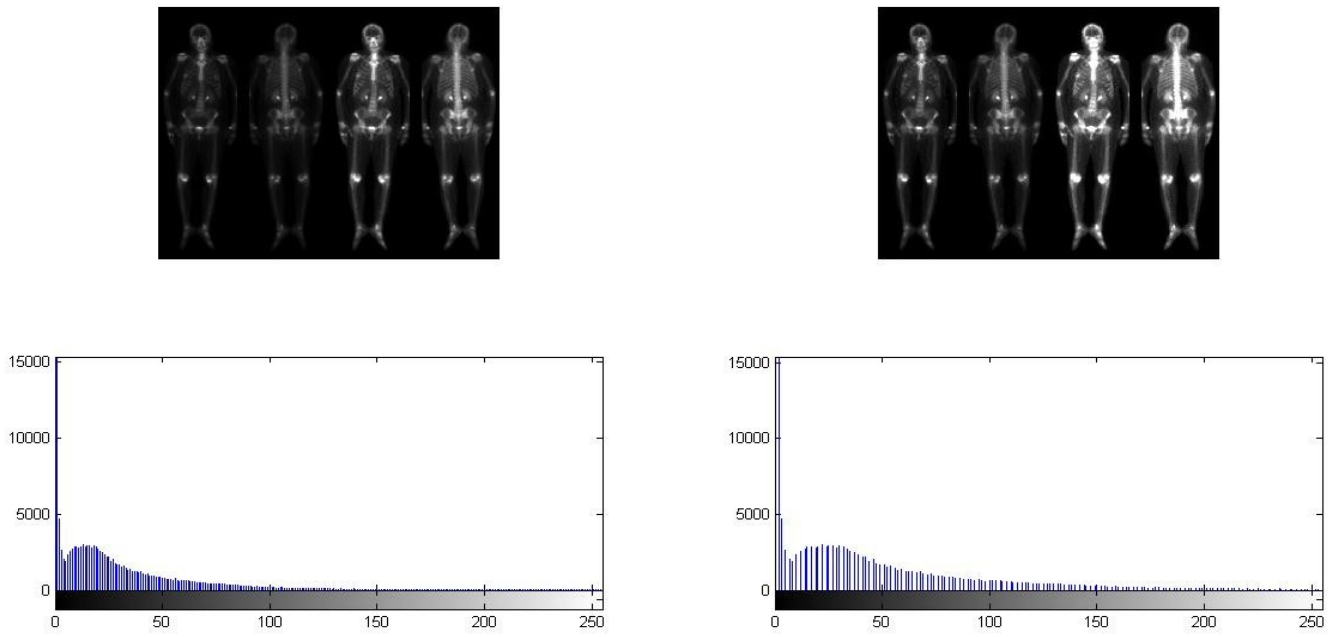

***Figure 4-20. Contrast stretch image technique; at left side the original image with histogram and at right side the enhanced image using contrast stretch image technique* from test (B5)**

4.3. Result of bone scan image number (3):

Used four types of techniques

1.Contrast-limited adaptive histogram equalization (CLAHE)

Step one: image reading as shown in figure 4-21:

I= imread ('bonescan.jpg');

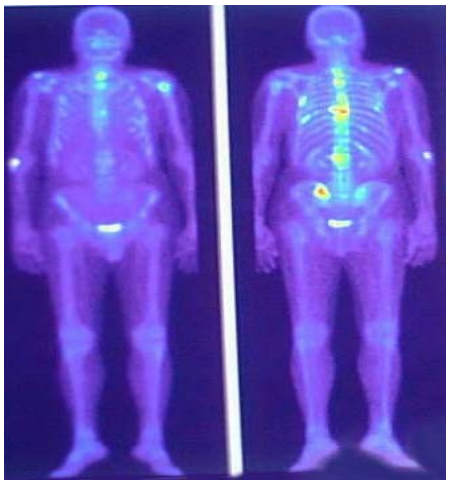

Figure 4-21. The original bone scan image test (C1)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: Perform CLAHE

A = adapthisteq(I,'clipLimit',0.02,'Distribution','rayleigh');

Step four: Display the results with image histogram as shown in figure 4-22

figure, imshow(I)

figure, imshow(A)

figure, imhist(I)

figure, imhist(A)

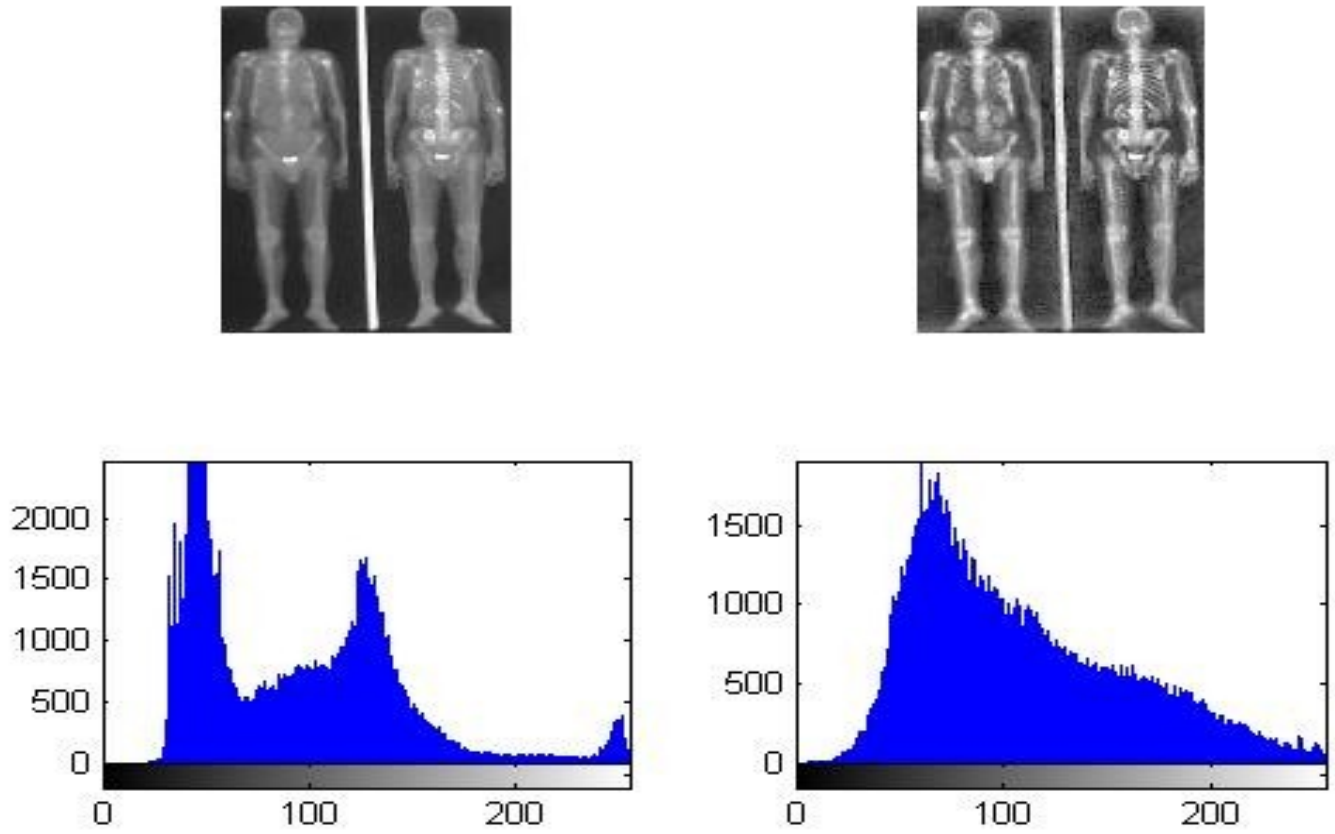

Figure 4-22. CLAHE technique; at left side the gray scale image with histogram and at right side the enhanced image using CLAHE technique from test (C1)

2.Enhance contrast using histogram equalization:

Step one: image reading as shown in figure 4-23:

I= imread ('bonescan.jpg');

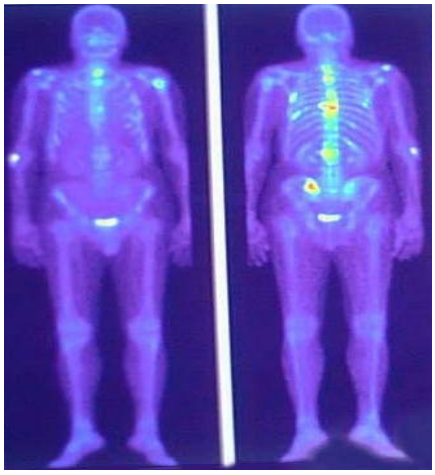

Figure 4-23. The original bone scan image test (C2)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: Perform Adjust code**.**

J = histeq(I);

Step four: Display the results with image histogram as shown in figure 4-24

figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)

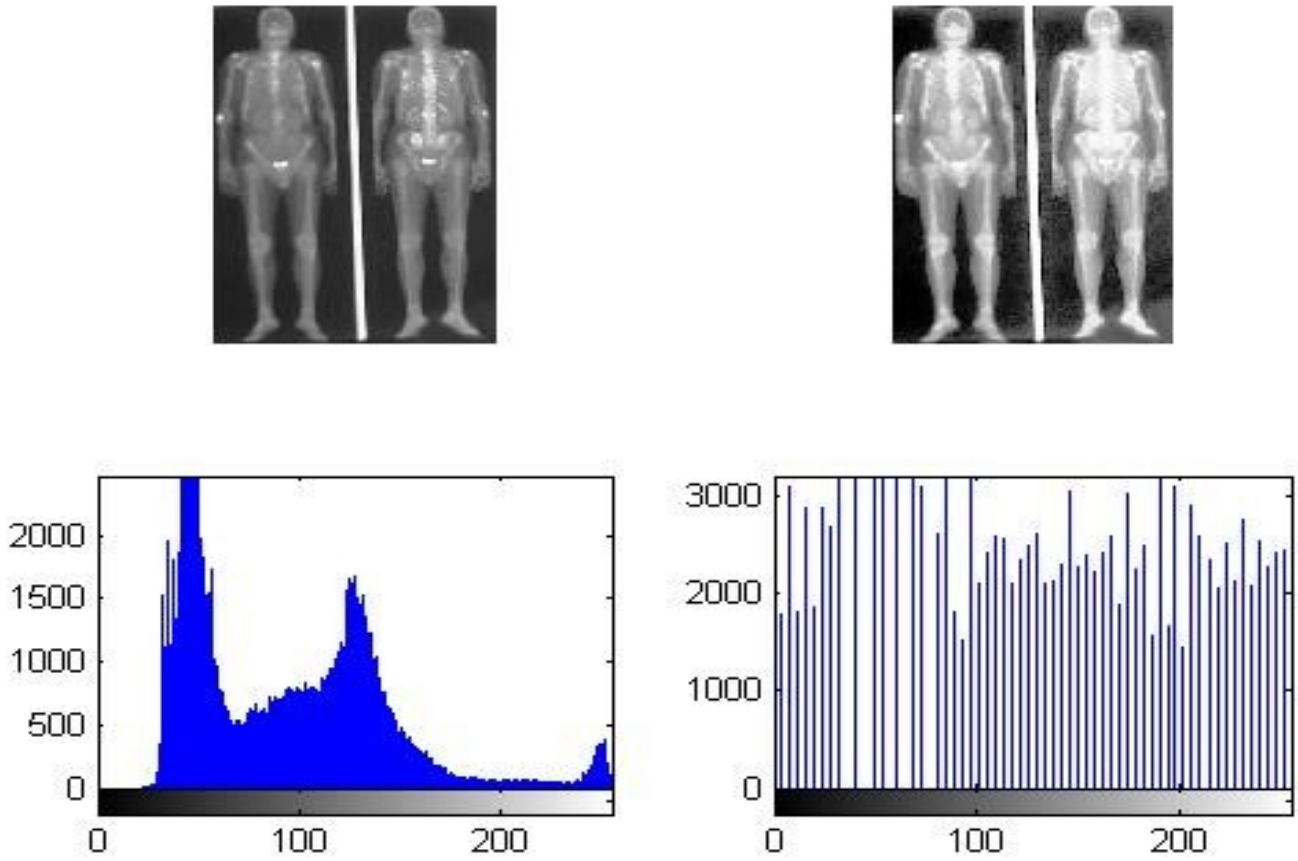

Figure 4-24. histogram equalization technique; at left side the gray scale image with histogram and at right side the enhanced image using histogram equalization technique from test (C2)

3.2-D median filtering:

Step one: image reading as shown in figure 4-25:

I= imread ('bonescan.jpg');

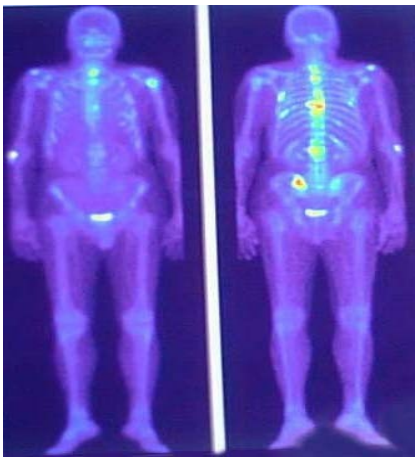

Figure 4-25. The original bone scan image test (C3)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: Perform Adjust code**.**

J = imnoise(I,'salt & pepper',0.02);

K = medfilt2(J);

Step four: Display the results with image histogram as shown in figure 4-26

figure, imshow(J)

figure, imshow(K)

figure, imhist(J)

figure, imhist(K)

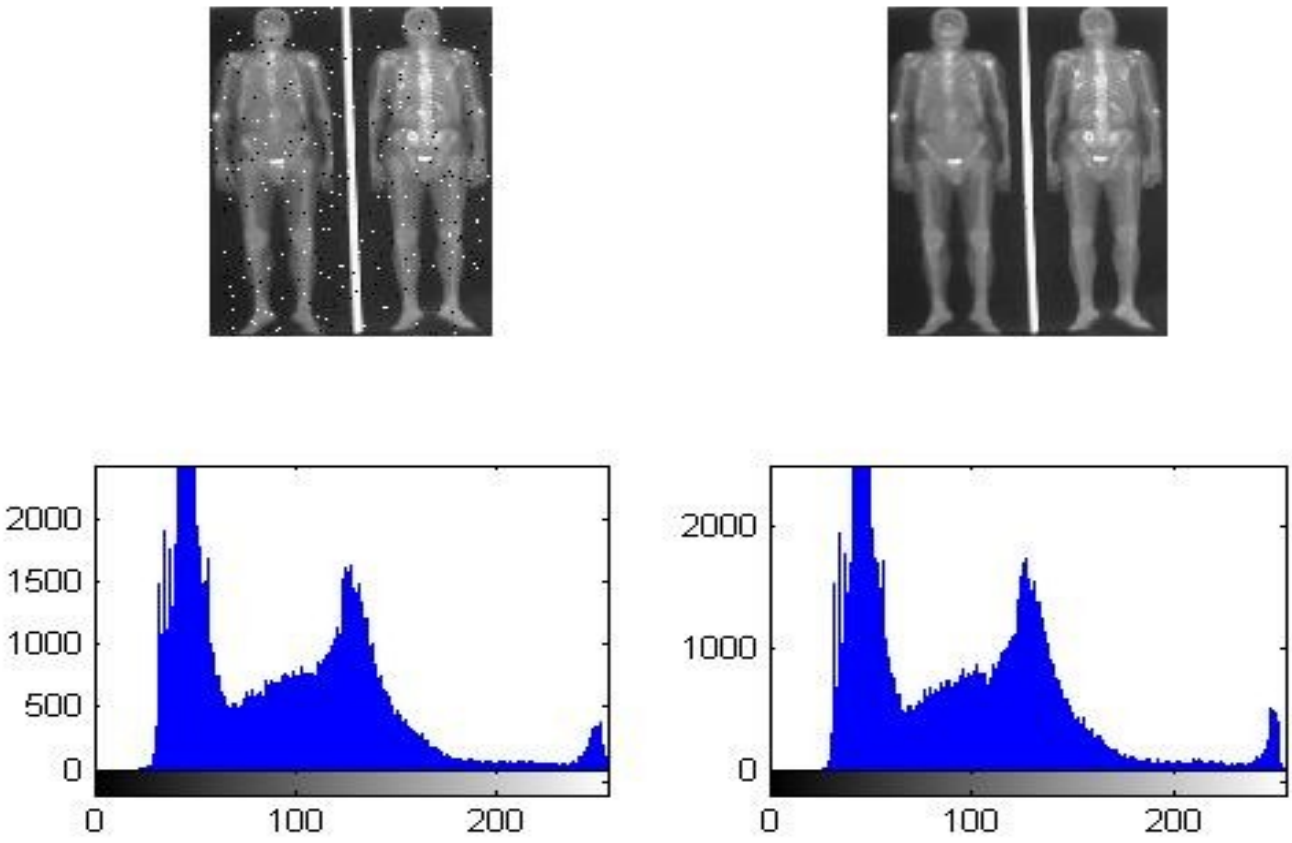

Figure 4-26. 2-D median filtering technique; at left side the blurring image with histogram and at right side the enhanced image using 2-D median filtering technique from test (C3)

4.contrast stretch image:

Step one: image reading as shown in figure 4-27:

I= imread ('bonescan.jpg');

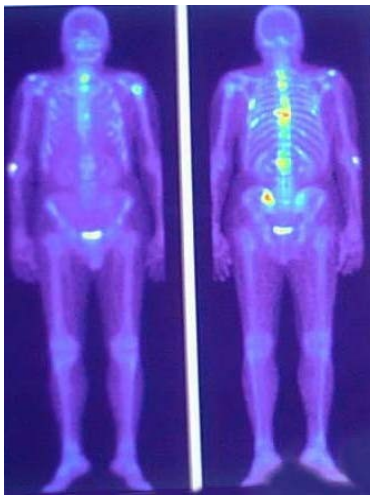

Figure 4-27. The original bone scan image test (C4)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: used contrast stretch image code.

J = imadjust(I,stretchlim(I),[]);

Step four: Display the results with image histogram as shown in figure 4-28

figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)

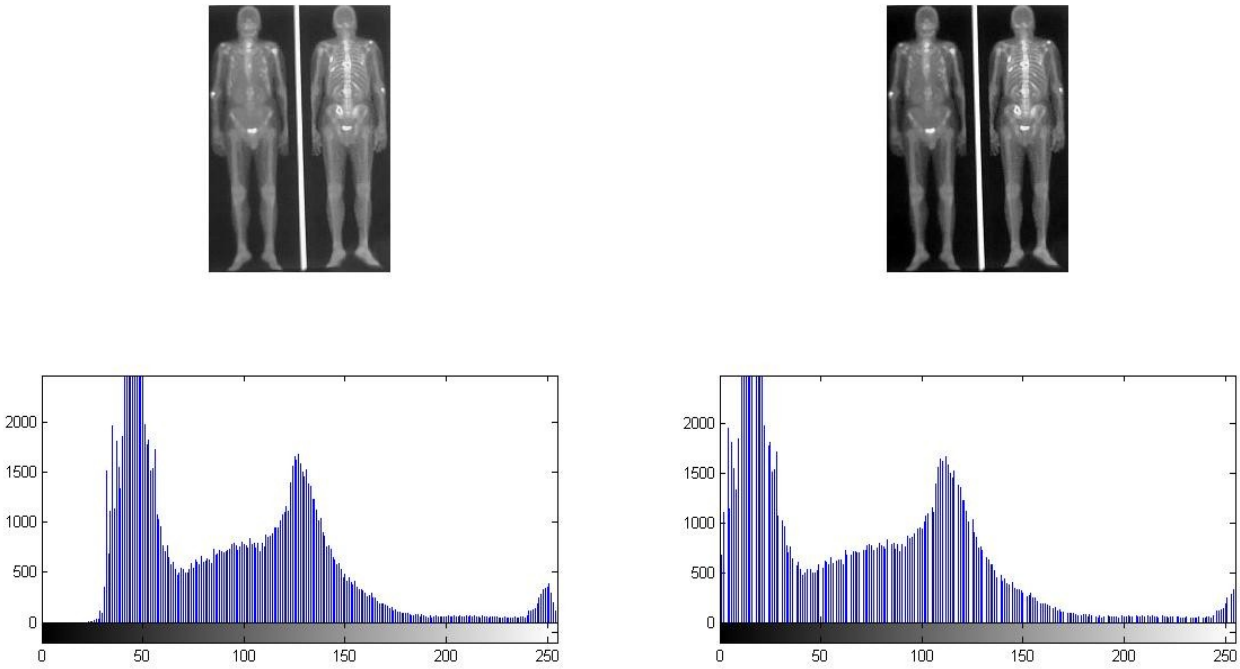

***Figure 4-28. Contrast stretch image technique; at left side the gray scale image with histogram and at right side the enhanced image using contrast stretch image technique* from test (C4)**

4. 4. Result of bone scan image number (4):

1.Contrast-limited adaptive histogram equalization (CLAHE)

Step one: image reading as shown in figure 4-29:

I= imread ('bonescan.jpg');

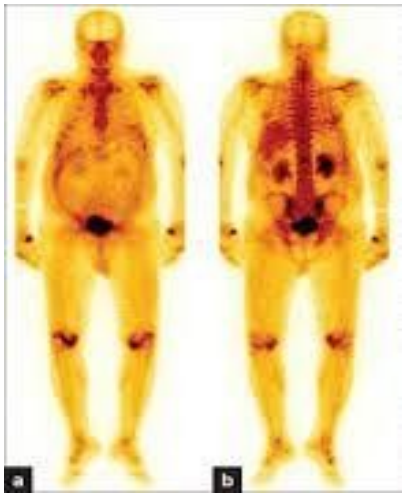

Figure 4-29. The original bone scan image test (D1)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: Perform CLAHE

A = adapthisteq(I,'clipLimit',0.02,'Distribution','rayleigh');

Step four: Display the results with image histogram as shown in figure 4-30

figure, imshow(I)

figure, imshow(A)

figure, imhist(I)

figure, imhist(A)

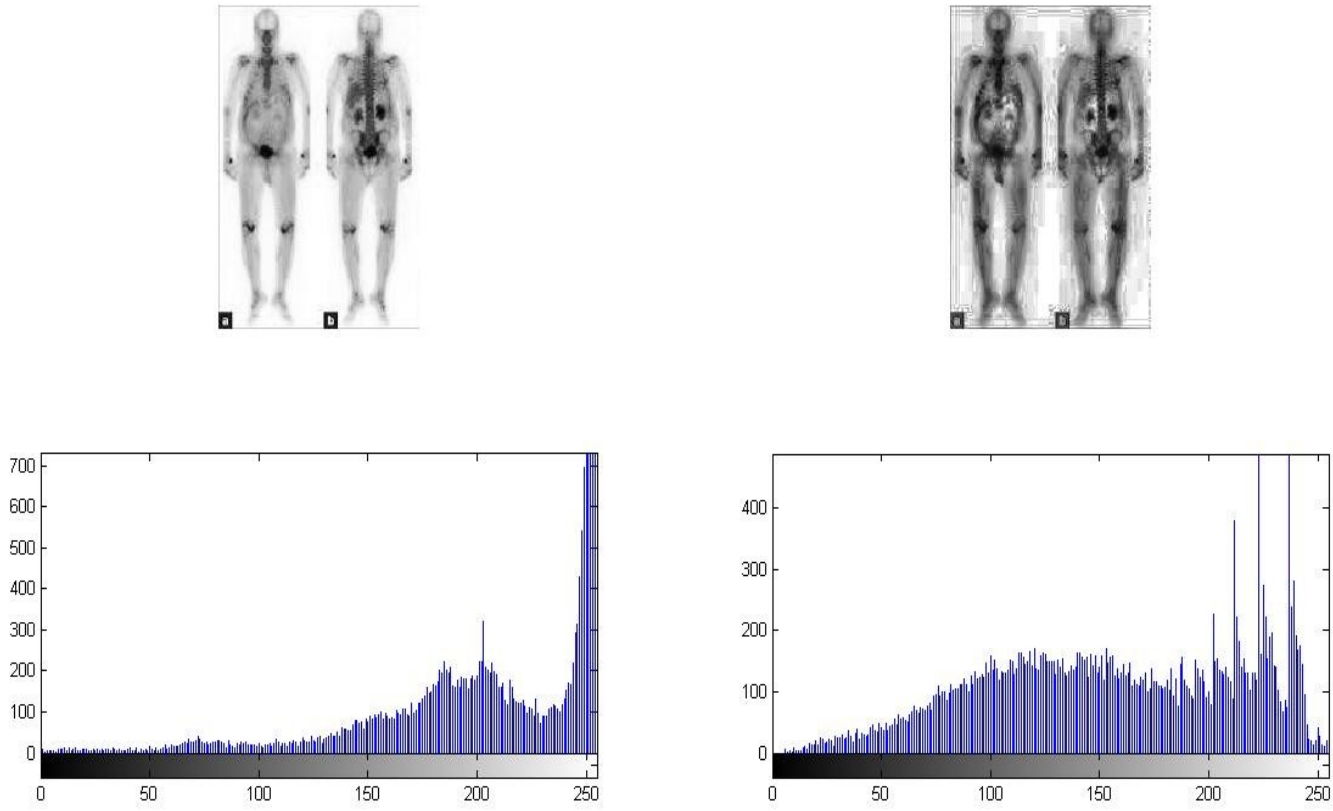

Figure 4-30. CLAHE technique; at left side the gray scale image with histogram and at right side the enhanced image using CLAHE technique from test (D1)

2.Enhance contrast using histogram equalization:

Step one: image reading as shown in figure 4-31:

I= imread ('bonescan.jpg');

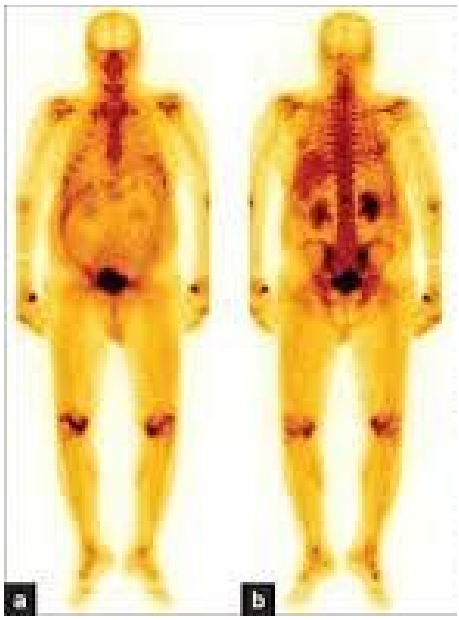

Figure 4-31. The original bone scan image test (D2)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: Perform Adjust code**.**

J = histeq(I);

Step four: Display the results with image histogram as shown in figure 4-32

figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)

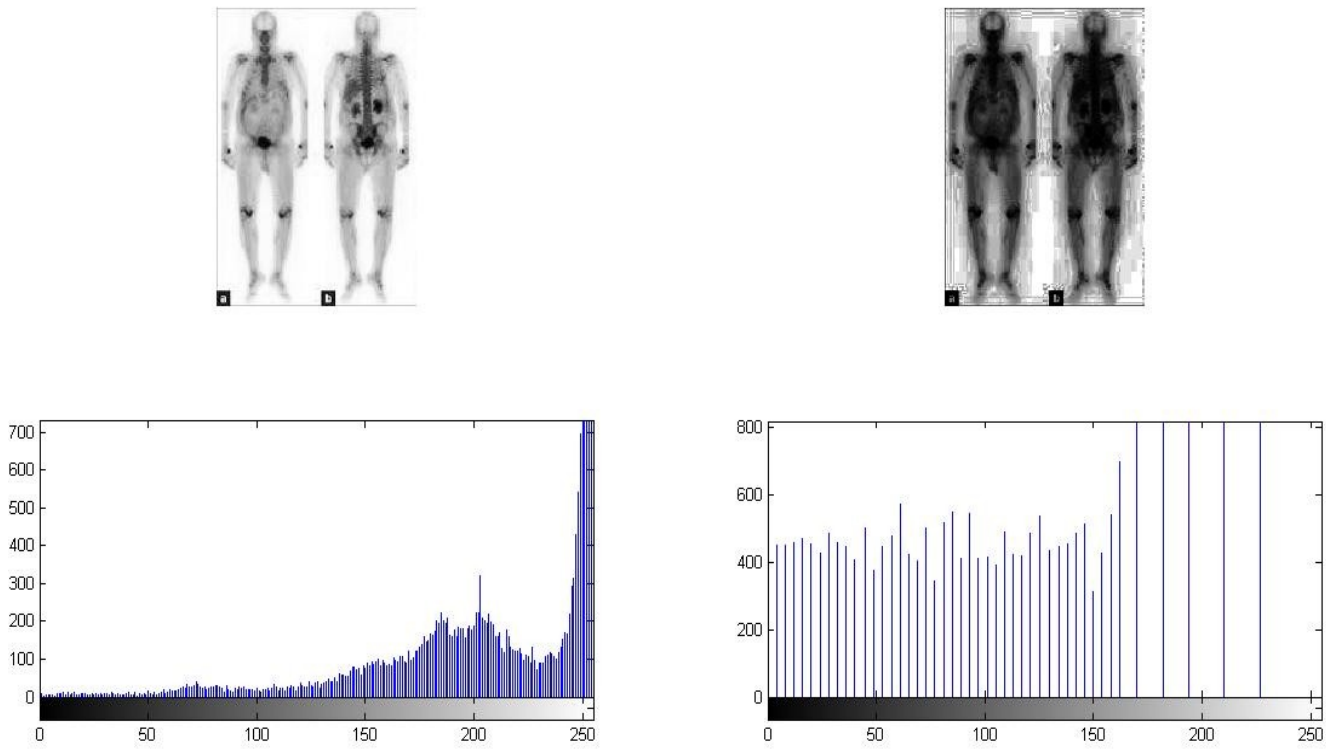

Figure 4-32. histogram equalization technique; at left side the gray scale image with histogram and at right side the enhanced image using histogram equalization technique from test (D2)

3.2-D median filtering:

Step one: image reading as shown in figure 33

I= imread ('bonescan.jpg');

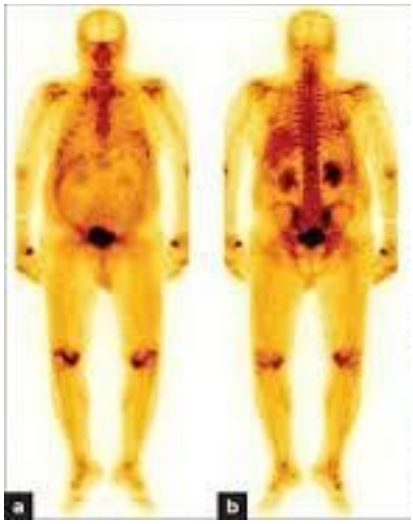

Figure 4-33. The original bone scan image test (D3)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: Perform Adjust code**.**

J = imnoise(I,'salt & pepper',0.02);

K = medfilt2(J);

Step four: Display the results with image histogram as shown in figure 4-34

figure, imshow(J)

figure, imshow(K)

figure, imhist(J)

figure, imhist(K)

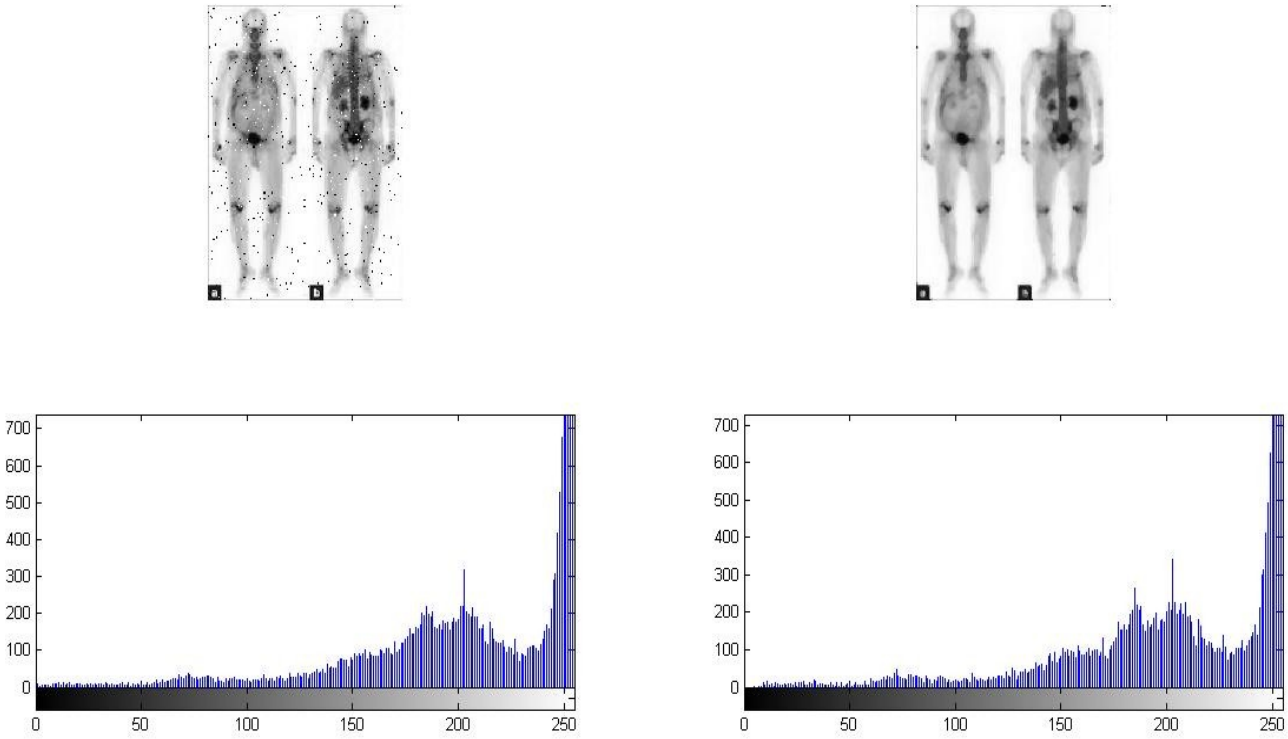

Figure 4-34. 2-D median filtering technique; at left side the blurring image with histogram and at right side the enhanced image using 2-D median filtering technique from test (D3)

4.contrast stretch image:

Step one: image reading as shown in figure 4-35:

I= imread ('bonescan.jpg');

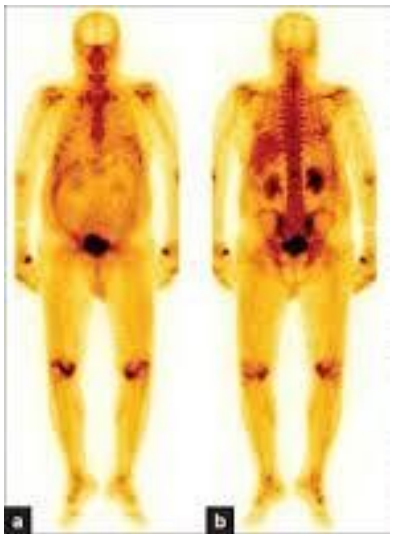

Figure 4-35. The original bone scan image test (D4)

Step two: Convert image to gray scale format

I=rgb2gray(I)

Step three: used contrast stretch image code.

J = imadjust(I,stretchlim(I),[]);

Step four: Display the results with image histogram as shown in figure 4-36

figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)

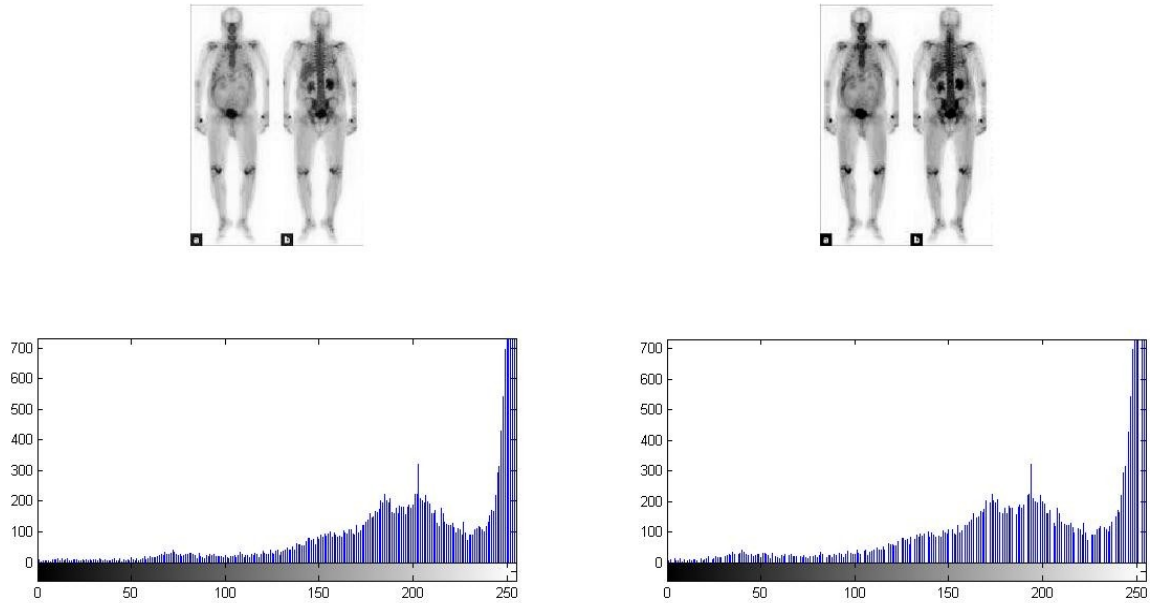

***Figure 4-36. Contrast stretch image technique; at left side the original image with histogram and at right side the enhanced image using contrast stretch image technique* from test (D4)**

4.5. Result of bone scan image number (5):

1.Contrast-limited adaptive histogram equalization (CLAHE)

Step one: image reading as shown in figure 4-37:

I= imread ('bonescan.jpg');

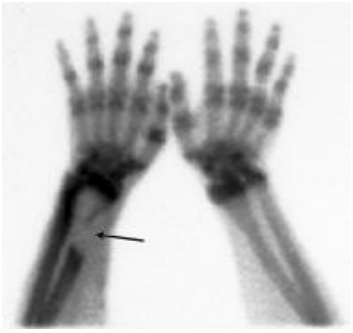

Figure 4-37. The original bone scan image test (E1)

Step two: Convert indexed image to true-color (RGB) format

RGB = ind2rgb(I);

Step three: Convert image to L*a*b* color space

```
cform2lab = makecform('srgb2lab');
LAB = applycform(RGB, cform2lab);
```

Step four: Scale values to range from 0 to 1

```
L = LAB(:,:,1)/100;
```

Step five: Perform CLAHE

```
LAB(:,:,1) = adapthisteq(L,'NumTiles',...
                    [8 8],'ClipLimit',0.005)*100;
```

Step Six: Display the results with image histogram as shown in figure 4-38

```
figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)
```

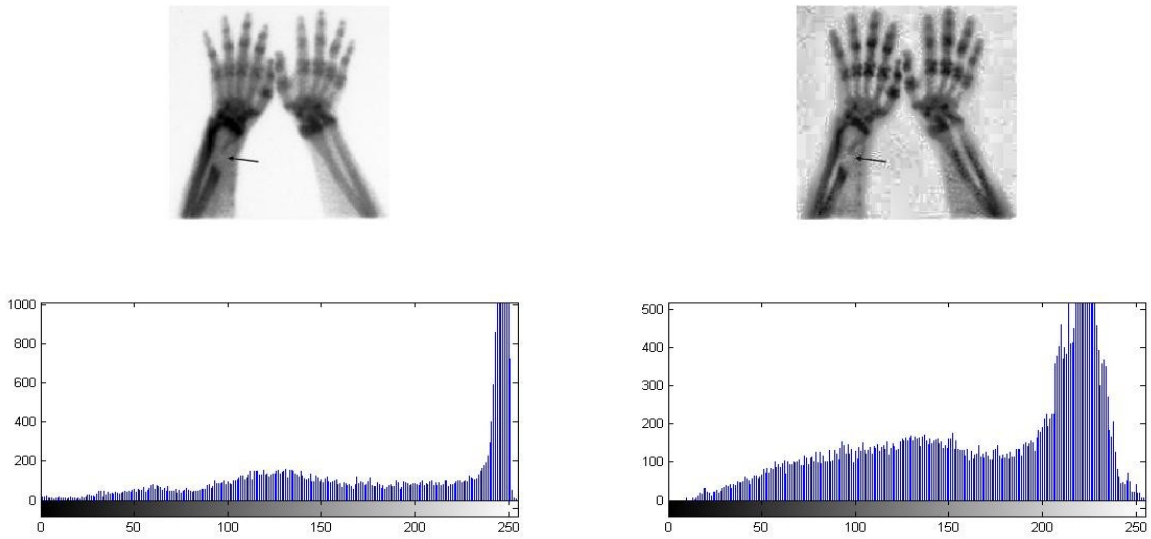

Figure 4-38. CLAHE technique; at left side the original image with histogram and at right side the enhanced image using CLAHE technique from test (E1)

2.Enhance contrast using histogram equalization:

Step one: image reading as shown in figure 4-39:

```
I= imread ('bonescan.jpg');
```

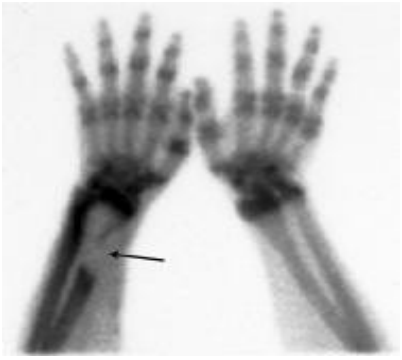

Figure 4-39. The original bone scan image test (E2)

Step two: Convert indexed image to true-color (RGB) format

```
RGB = ind2rgb(I);
```

Step three: Convert image to L*a*b* color space

```
cform2lab = makecform('srgb2lab');
LAB = applycform(RGB, cform2lab);
```

Step four: Scale values to range from 0 to 1

```
L = LAB(:,:,1)/100;
```

Step five: used histogram equalization code.

```
J = histeq(I);
```

Step Six: Display the results with image histogram as shown in figure 4-40

```
figure, imshow(I)

figure, imshow(J)

figure, imhist(I)

figure, imhist(J)
```

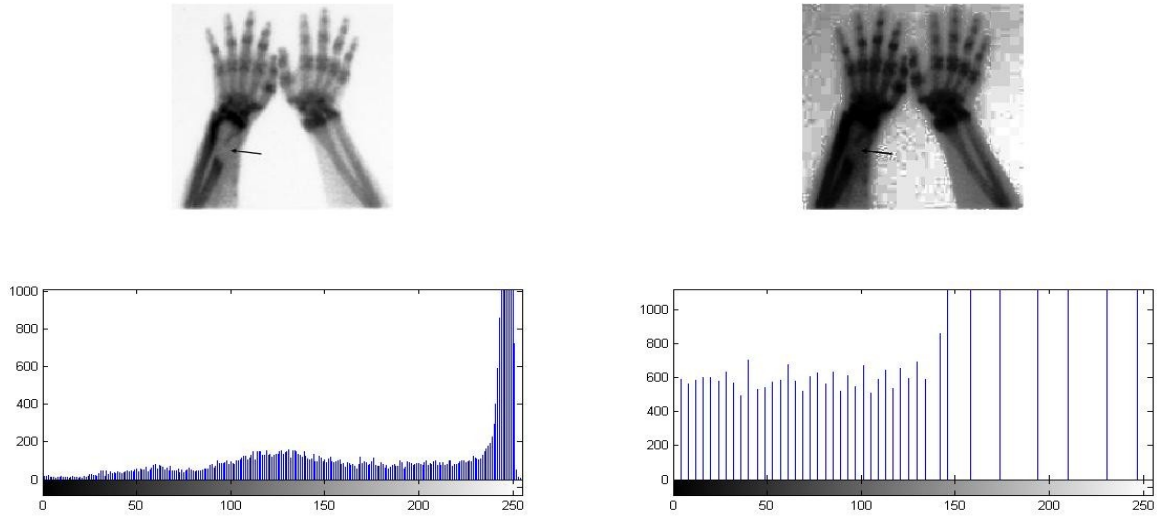

Figure 4-40. histogram equalization technique; at left side the original image with histogram and at right side the enhanced image using histogram equalization technique from test (E2)

3.2-D median filtering:

Step one: image reading as shown in figure 4-41:

I= imread ('bonescan.jpg');

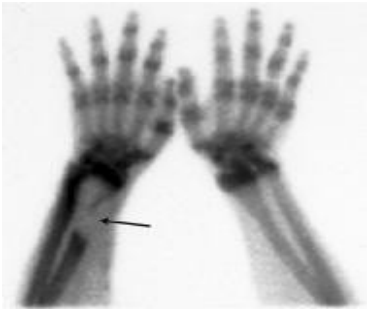

Figure 4-41. The original bone scan image test (E3)

Step two: Convert indexed image to true-color (RGB) format

RGB = ind2rgb(I);

Step three: Convert image to L*a*b* color space

cform2lab = makecform('srgb2lab');

LAB = applycform(RGB, cform2lab);

Step four: Scale values to range from 0 to 1

L = LAB(:,:,1)/100;

Step five: used 2-D median filtering.

J = imnoise(I,'salt & pepper',0.02);

K = medfilt2(J);

Step Six: Display the results with image histogram as shown in figure 4-42

figure, imshow(J)

figure, imshow(K)

figure, imhist(J)

figure, imhist(K)

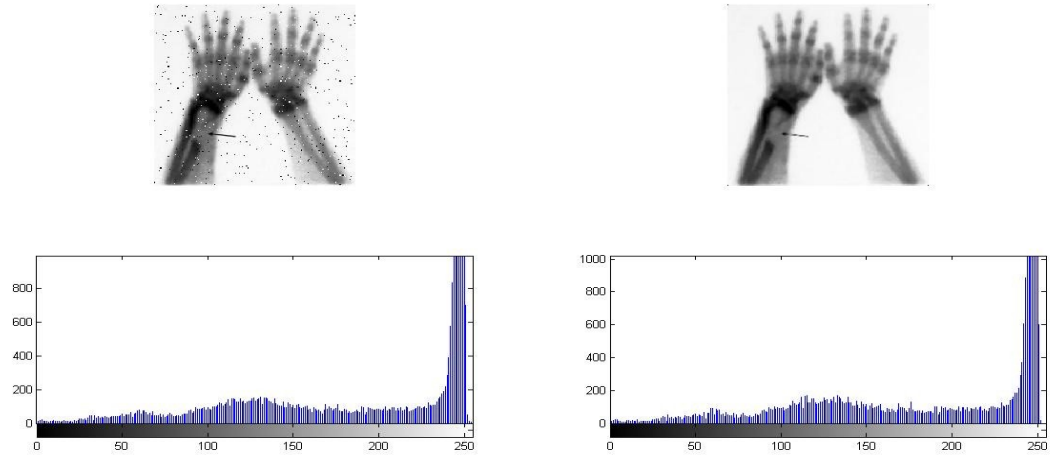

Figure 4-42. 2-D median filtering technique; at left side the blurring image with histogram and at right side the enhanced image using 2-D median filtering technique from test (E3)

4.contrast stretch image:

Step one: image reading as shown in figure 4-43:

I= imread ('bonescan.jpg');

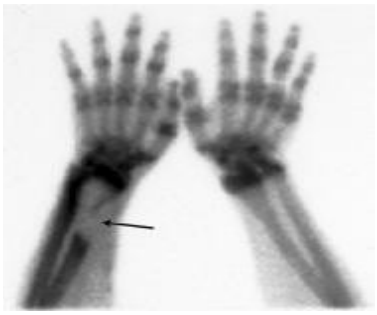

Figure 4-43. The original bone scan image test (E4)

Step two: Convert indexed image to true-color (RGB) format

RGB = ind2rgb(I);

Step three: Convert image to L*a*b* color space

cform2lab = makecform('srgb2lab');

LAB = applycform(RGB, cform2lab);

Step four: Scale values to range from 0 to 1

L = LAB(:,:,1)/100;

Step five: used contrast stretch image code.

J = imadjust(I,stretchlim(I),[]);

Step Six: Display the results with image histogram as shown in figure 4-44

figure, imshow(I) , figure, imshow(J)

figure, imhist(I), figure, imhist(J)

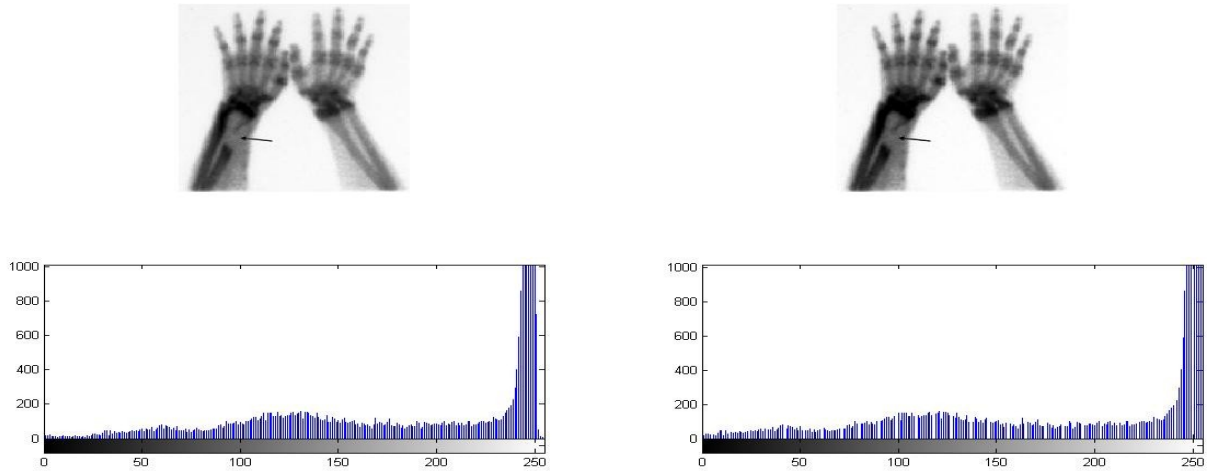

***Figure 4-44. Contrast stretch image technique; at left side the original image with histogram and at right side the enhanced image using contrast stretch image technique* from test (E4)**

More cases studies for patient 6 to 10 were displayed in appendix from page I.

Chapter Five

Discussion, Conclusion and Recommendations

5.1. Discussion:

Advanced techniques of image processing and analysis find widespread use in medicine. In medical applications, image data are used to gather details regarding the process of patient imaging whether it is a disease process or a physiological process. Information provided by medical images has become a vital part of today's patient care. The images generated in medical applications are complex and vary notably from application to application. Nuclear medicine images show characteristic information about the physiological properties of the structures-organs. In order to have high quality medical images for reliable diagnosis, the processing of image is necessary. The scope of image processing and analysis applied to medical applications is to improve the quality of the acquired image and extract quantitative information from medical image data in an efficient and accurate way. In Nuclear Medicine, there are two main methods of patient imaging, the imaging with Planar Imaging, Dynamic Imaging or SPECT and the PET. In this study data analyzed by using MatLab program to enhance the contrast within the bones, the gray levels in both enhanced and unenhanced images and noise variance. The technique used for this study were Contrast-limited adaptive histogram equalization (CLAHE) which operated on small regions in the image, called tiles, rather than the entire image, each tile's contrast was enhanced, so that the histogram of the output region approximately matches the histogram specified by the 'Distribution' parameter., Enhance contrast using so that the histogram of the output region approximately matches the histogram specified by the 'Distribution' parameter. The neighboring tiles were then combined using bilinear interpolation to eliminate artificially induced boundaries. The contrast, especially in homogeneous areas, could be limited to avoid amplifying any noise that might be present in the image as shown in figure 4-2 and figure 4-12. The histogram

equalization enhanced the contrast of images (bone scan) by transforming the values in an intensity image, or the values in the colormap of an indexed image, so that the histogram of the output image approximately matched a specified histogram as shown in figure 4-4 and figure 4-14. Adjust image intensity values or colormap used to enhance the images of bone scan by increased of contract of the image, it mapped the intensity values in grayscale image as shown in original image (figure 4-1) to new values in figure 4-6 and figure 4-16 such that 1% of data is saturated at low and high intensities of I. 2-D median filtering used as nonlinear operation which often used in image processing to reduce "salt and pepper" noise in figure 4-7 and figure 4-12 from the images (bone scan) as in figure 4-8 and figure 4-18. A median filter was more effective than convolution when the goal was to simultaneously reduce noise and preserve edges.

Contrast stretch image used to enhance of the images (bone scan) within which a two-element vector of pixel values that specify lower and upper limits that can be used for contrast stretching image as in figure 4-10 and figure 4-20. The results of this technique agreed the results of Robiul et al, (2011), Nasrul et al, (2012), Gupta et al, (2012) and Smriti et al, (2012) who used non-linear filtering based methods to enhance the nuclear medicine images. The anther technique was Convolution kernel filter. Filtering is a technique for modifying or enhancing an image. For example, researchers can filter an image to emphasize certain features or remove other features. Image processing operations implemented with filtering include smoothing, sharpening, and edge enhancement. Filtering is a neighborhood operation, in which the value of any given pixel in the output image is determined by applying some algorithm to the values of the pixels in the neighborhood of the corresponding input pixel. A pixel's neighborhood is some set of pixels, defined by their locations relative

to that pixel. Linear filtering is filtering in which the value of an output pixel is a linear combination of the values of the pixels in the input pixel's neighborhood.

5.2.Conclusion:

The very small detail's of bone scan could be clearly appear at used this techniques, also the sensitivity is increased in this study and the quality of images is increased by using Matlab techniques.

The histogram is appear the significant different of enhance the images and used non-linear filtering based methods to enhance the nuclear medicine images by reduce of "salt and pepper" noise.

Implemented the image processing operations with filtering to smoothing, sharpening and edge enhancement.

5.3.Recommendations:

- The fspecial, noise removal and Wiener filtering are recommended to study x-rays images in order to reduce the speckle without fully eliminating the image edges.

- Using both hat-top and blind Deconvolution algorithm is recommended as a new approach of noise estimation using image processing technique (MATLAB).
- Future works are recommended to involve investigation of uncompressed ultrasound images to verify the differences of image quality with compressed images

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